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PHASE II-TITLE I ENGINEERING ASSESSMENT OF INACTIVE URANIUM MILL TAILINGS NATURITA SITE, NATURITA, COLORADO

NOVEMBER 1977

PREPARED FOR

UNITED STATES DEPARTMENT OF ENERGY
GRAND JUNCTION, COLORADO, CONTRACT NO. E(05-1)-1658

BY

Ford, Bacon & Davis Utah Inc.

FBDU 130-07

PHASE II - TITLE I

ENGINEERING ASSESSMENT OF

INACTIVE URANIUM MILL TAILINGS

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By

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NOTICE

This Phase II - Title I Engineering Assessment has been performed under ERDA Contract No. E(05-1)-1658 executed on June 23, 1975 between the U.S. Energy Research and Development Administration and Ford, Bacon & Davis Utah Inc. On October 1, 1977, ERDA was incorporated into the U.S. Department of Energy; hence, this engineering assessment is issued for the DOE, the present responsible agency.

FOREWORD

This report entitled, "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Naturita Site, Naturita, Colorado", was prepared under the U.S. Energy Research and Development Administration (ERDA) Contract No. E(05-1)-1658. It is one of a series of reports on inactive uranium millsites that addresses the radiological problems and estimated costs of remedial measures that would reduce exposure of the general public. Title I is not a scientific study but an engineering assessment to determine the relative magnitude of the hazards associated with each site, to identify reasonable remedial action options for each site, and to estimate the remedial action costs. If additional information that may alter or have an impact on a final remedial action decision for any site is required, it can be obtained during the Title II Engineering Effort. Chapter 1 of this report is a summary and is published under separate cover for those not requiring all the details of this report.

Ford, Bacon & Davis Utah Inc. (FB&DU) under supplemental authorization currently is investigating uranium mill tailings stabilization techniques. This research could modify some of the estimated costs in this report.

Also, FB&DU acknowledges the excellent cooperation and assistance given in this engineering assessment. Particular recognition is due the ERDA personnel of both the Germantown, MD and Grand Junction, CO offices and also the Union Carbide Corporation personnel of the Health Physics Division, Oak Ridge National Laboratory, who provided field radiological measurements and radiometric analyses of samples. The preparation of this report could not have been accomplished without the cooperation and assistance of the following:

(1) The Environmental Protection Agency for consultation, data, and information from prior surveys and studies with notable assistance from the Office of Radiation Programs, Las Vegas, Nevada

(2) The State of Colorado: Department of Health, Mr. A. J. Hazle and Mr. G. A. Franz

(3) EG&G, Las Vegas, Nevada; Mr. Jack Doyle, for aerial photography

(4) Center for Health and Environmental Studies, Brigham Young University, Provo, Utah; for socioeconomic studies

(5) Foote Mineral Company: Mr. R. L. Anderson, Mr. A. E. Curtis

(6) Ranchers Exploration and Development Corporation: Mr. David K. Hogan and Mr. Jamiesen K. Deuel

ABSTRACT

Ford, Bacon & Davis Utah Inc. has performed an engineering assessment of the problems resulting from the existence of radioactive uranium mill tailings at Naturita, Colorado. The Phase II-Title I services include the preparation of topographic maps, the performance of core drillings sufficient to determine areas and volumes of tailings, the performance of radiometric measurements to determine the extent of radium contamination, the evaluation of resulting radiation exposures of individuals and nearby populations, the investigation of site hydrology and meteorology, and the costing of alternative corrective actions.

Radon gas release from the 704,000 tons of tailings at the Naturita site constitutes the most significant environmental impact although windblown tailings and external gamma radiation are also factors.

Ranchers Exploration and Development Company has been licensed by the State of Colorado to reprocess the tailings at a location 3 mi from the present site where they will be stabilized for long-term storage.

The remedial action options include remedial action for structures in Naturita and Nucla (Option I) at an estimated cost of $270,000 and remedial action for structures and open land adjacent to the tailings site (Option II) at an estimated cost of $950,000.

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GLOSSARY

Abbreviations/Terms	Definitions
absorbed dose	Radiation energy absorbed per unit mass.
A-E	Architect-Engineer.
AEC	Atomic Energy Commission.
alpha particle (α)	A positively charged particle emitted from certain radioactive material. It consists of two protons and two neutrons, hence is identical with the nucleus of the helium atom. It is the least penetrating of the common radiation (α, β, γ), hence is not dangerous unless alpha-emitting substances have entered the body.
amenability	The relative ease with which a mineral(s) can be removed from an ore by a particular process.
anomaly (mobile gamma survey)	Any location detected by the mobile gamma survey where the recorded counts per second (c/s) from a large gamma-ray detector exceed the determined background for that area by 50 or more c/s.
aquifer	A water-bearing formation below the surface of the earth; the source of wells. A confined aquifer is overlain by relatively impermeable rock. An unconfined aquifer is one associated with the water table.
atmospheric pressure	Pressure exerted on the earth by the mass of the atmosphere surrounding the earth; expressed in inches of mercury (at sea level and $0^{o}C$, standard pressure is 29.921 in. Hg).
background radiation	Naturally occurring low-level radiation to which all life is exposed. Background radiation levels vary from place to place on the earth.
beta particle (β)	A particle emitted from some atoms undergoing radioactive decay. A negatively charged beta particle

	is identical to an electron. A positively charged beta particle is called a positron. Beta radiation can cause skin burns and beta-emitters are harmful if they enter the body.
BEIR	Biological Effects of Ionizing Radiation.
BOM (USBOM)	Bureau of Mines.
CHES	Center for Health and Environmental Studies, Brigham Young University, Provo, Utah.
Ci	Curie (the unit of radioactivity of any nuclide, defined as precisely equal to 3.7×10^{10} disintegrations/second).
daughter product	The nuclide remaining after a radioactive decay. A daughter atom may itself be radioactive, producing further daughter products.
diurnal	Daily, cyclic (happening each day or during the day).
dose equivalent	A term used to express the amount of effective radiation when modifying factors have been considered (the numerical product of absorbed dose and quality factor).
EGR	External gamma radiation (gamma radiation emitted from a source(s) external to the body, as opposed to internal gamma radiation emitted from ingested or inhaled sources).
EPA (USEPA)	Environmental Protection Agency.
ERDA (USERDA)	Energy Research and Development Administration.
ERDA-GJO	Energy Research and Development Administration-Grand Junction Office.
erg	The basic unit of work or energy in the centimeter-gram-second.

	system (1 erg is equal to 7.4 x 10^8 ft-lb).
exposure	Related to electrical charge produced in air by ionizing radiation per unit mass of air.
exhalation	Emission of radon from earth (usually thought of as coming from a uranium tailings pile, but actually from any location).
FB&DU	Ford, Bacon & Davis Utah Inc.
gamma background	Natural gamma ray activity everywhere present, originating from two sources: (1) cosmic radiation, bombarding the earth's atmosphere continually, and (2) terrestrial radiation. Whole body absorbed dose equivalent in the U.S. due to natural gamma background ranges from about 60 to about 125 mrem/yr.
gamma ray	High energy electromagnetic radiation emitted from the nucleus of a radioactive atom, with specific energies for the atoms of different elements and having high penetrating power.
GJO	Grand Junction Office.
ground water	Subsurface water in the zone of full saturation which supplies wells and springs.
health effect	Adverse physiological response from tailings (in this report, one health effect is defined as one case of cancer from exposure to radioactivity).
heap leaching	A process for removing uranium from ore, tailings, or other material wherein the material is placed on an impermeable pad and wetted with appropriate reagents. The uranium solution is collected for further processing.
HEW (USHEW)	Department of Health, Education, and Welfare.

insult	Negative impact on the environment or the health of individuals.
Interim Drinking Water Standards (EPA)	Title No. 40 of the Code of Federal Regulations, Chapter 1, Part 141. dated Dec 24, 1975; scheduled to become effective Jun 24, 1977.
iso-exposure line	A line drawn on a map to connect all points having the same exposure rate.
isotope	One of two or more atoms with the same atomic numbers (the same chemical element) but with different atomic weights. Isotopes usually have very nearly the same chemical properties, but somewhat different physical properties.
JCAE	Joint Committee on Atomic Energy.
knot	A unit of velocity, approximately equal to 1.15 mi/hr.
μR/hr	Microroentgen per hour.
mR/hr	Milliroentgen per hour.
MeV	Million electron volts.
MPC	Maximum permissible concentration (the highest concentration in air or water of a particular radionuclide permissible for occupational or general exposure without taking steps to reduce exposure).
NAS	National Academy of Sciences.
NIOSH	National Institute for Occupational Safety and Health.
noble gas	One of the gases, such as helium, neon, radon, etc., with completely filled electron shells which is therefore chemically inert.
NRC	Nuclear Regulatory Commission.

nuclide	A general term applicable to all atomic forms of the elements; nuclides comprise all the isotopic forms of all the elements. Nuclides are distinguished by their atomic number, atomic mass, and energy state.
ORNL	Oak Ridge National Laboratory.
ORP-LVF (EPA)	Office of Radiation Programs, Las Vegas Facility (Environmental Protection Agency).
pCi/l	Picocurie per liter.
PHS (USPHS)	Public Health Service.
QF	Quality factor (an assigned factor which denotes the modification of the effectiveness of a given absorbed dose by the linear energy transfer).
R	Roentgen (a unit of exposure to ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying 1 electrostatic unit of electrical charge, either positive or negative, in 1 cubic centimeter of dry air under standard conditions, numerically equal to 2.58×10^{-4} coulombs/kg).
rad	The basic unit of absorbed dose of ionizing radiation. A dose of 1 rad means the absorption of 100 ergs of radiation energy per gram of absorbing material.
radioactivity	The spontaneous decay or disintegration of an unstable atomic nucleus, usually accompanied by the emission of ionizing radiation.
radioactive decay chain	A succession of nuclides each of which transforms by radioactive disintegration into the next until a stable nuclide results. The first member is called the parent, the intermediate members are called daughters, and the final stable member is called the end product.

radium	A radioactive element, chemically similar to barium, formed as a daughter product of uranium (^{238}U). The most common isotope of radium, ^{226}Ra, has a half-life of 1,620 yr. Radium is present in all uranium-bearing ores. Trace quantities of both uranium and radium are found in all areas, contributing to the gamma background.
radon	A radioactive, chemically inert gas, having a half-life of 3.8 days (^{222}Rn); formed as a daughter product of radium (^{226}Ra).
radon background	Low levels of radon gas found in an area, due to the presence of radium in the soil.
radon concentration	The amount of radon per unit volume. In this assessment, the average value for a 24-hr period of atmospheric radon concentrations, determined by collecting data for each 30 min period of a 24-hr day and averaging these values.
radon daughter	One of several short-lived radioactive daughter products of radon (several of the daughters emit alpha particles).
RDC	Radon daughter concentration (the concentration in air of short-lived radon daughters, expressed usually in pCi/l; also measured in terms of working level (WL).
radon flux	The quantity of radon emitted from a surface in a unit time per unit area (typical units are in pCi/cm^2-sec).
raffinate	The liquid part remaining after a product has been extracted in a solvent extraction process.
recharge	The processes by which water is absorbed and added to the zone of saturation of an aquifer, either directly into the formation or indirectly by way of another formation.

rem	(Acronym of roentgen equivalent man) The unit of dose of any ionizing radiation which produces the same biological effect as a unit of absorbed dose of ordinary X-rays, numerically equal to the absorbed dose in rads multiplied by the appropriate quality factor for the type of radiation. The rem is the basic recorded unit of accumulated dose to personnel.
residual value	The value of minerals in tailings material.
riprap	An irregular wall of broken rock, placed as a retaining wall, as a protection for dikes, etc.
sands	Relatively coarse-grained materials produced along with the slimes as waste products of ore processing in uranium mills (see tailings). These sands normally contain less radioactive material than the slimes.
scintillometer	A gamma-ray detection instrument normally utilizing a NaI crystal.
slimes	Extremely fine-grained materials, mixed with small amounts of water, produced along with the sands as waste products of ore processing in uranium mills (see tailings). Most of the radioactive material remaining in tailings is found in the slimes.
tailings	The remaining portion of a metal-bearing ore after the metal, such as uranium, has been extracted. Tailings also may contain other minerals or metals not extracted in the process (e.g. radium).
WL	Working level. A unit of radon daughter exposure, equal to any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy. This level is equivalent to the energy produced in the

CHAPTER 1

SUMMARY

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1.1 INTRODUCTION

The U.S. Energy Research and Development Administration (ERDA) has contracted with Ford, Bacon & Davis Utah Inc. (FB&DU) of Salt Lake City, Utah, to provide architect-engineering services in the assessment of the problems resulting from the existence of large quantities of radioactive uranium mill tailings at the sites of inactive mills in eight western states.

A preliminary survey (Phase I) was carried out by ERDA in cooperation with the EPA and the affected states and completed in October 1974. In the Summary Report[1], ERDA identified 17 sites in Arizona, Colorado, Idaho, New Mexico, Utah, and Wyoming for which practical remedial measures are to be evaluated. Subsequently, ERDA added five additional sites (Riverton and Converse County, Wyoming; Lakeview, Oregon; Falls City and Ray Point, Texas) to the list for a total of 22 sites. Most of these mills produced by far the greatest part of their output of uranium under contracts with the U.S. Atomic Energy Commission (AEC) during the period 1947 through 1970. After operations ceased, some companies made no attempt to stabilize the tailings, while others did so with varying degrees of success. Recently, concern has increased about the possible adverse effects to the general public from long-term exposure to low-level sources of radiation from the tailings piles and sites.

To date, the studies of radiation levels on and in the vicinity of these sites have been limited in scope. The data available were insufficient to permit assessment of risk to people with any degree of confidence in the conclusions reached. In addition, information on practicable measures to reduce radiation exposures and estimates of their projected costs are limited. The purpose of this study is to develop the necessary information to provide a basis for decision-making for appropriate remedial actions for each of these sites.

In assessing the significance of the conditions existing at the Naturita site, evaluations of the following factors were included:

(a) Exhalation of radon gas from the tailings

(b) On-site and off-site direct radiation

(c) Land contamination from windblown tailings

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[1] See end of chapter for references.

(d) Hydrology and contamination by water pathways

(e) Potential health impact

(f) Potential for extraction of additional metals from the tailings

Investigation of these and other factors led to the detailed evaluation of two alternatives. The first includes only remedial action at off-site structures and the second includes remedial action at off-site structures and cleanup of windblown contamination surrounding the tailings site. The formulation of these options assumes that the tailings will be removed from the site for reprocessing at a different location and that contaminated soil beneath the pile will be removed.

The estimated costs of carrying out the remedial work to implement each option depend on such parameters as the degree of decontamination to be achieved.

1.1.1 Background

On March 12, 1974, the Subcommittee on Raw Materials of the Joint Committee on Atomic Energy (JCAE), Congress of the United States, held hearings on S. 2566 and H.R. 11378, identical bills submitted by Senator Frank E. Moss and Representative Wayne Owens of Utah. The bills provided for a cooperative arrangement between the AEC and the State of Utah in the area of the Vitro tailings site in Salt Lake City.* The bills also provided for the assessment of and appropriate remedial action to limit the exposure of individuals to radiation from uranium mill tailings.

Dr. William D. Rowe, testifying in behalf of the Environmental Protection Agency (EPA), pointed out that there are other sites with similar problems. He recommended the problem be approached as a generic one, structured to address the most critical problem first.

Dr. James L. Liverman, testifying for the AEC, proposed that a comprehensive study should be made of all such piles, rather than treating the potential problem on a piece-meal basis. He proposed that the study be a cooperative two-phase undertaking by the states concerned and the appropriate federal agencies,

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*The proceedings of these hearings and the Summary Report on the Phase I Study were published by the JCAE as Appendix 3 to ERDA Authorizing Legislation for Fiscal Year 1976. Hearings before the Subcommittee on Legislation, JCAE, on Fusion Power, Biomedical and Environmental Research; Operational Safety; Waste Management and Transportation, Feb 18 and 27, 1975, Part 2.

such as the AEC and EPA. Phase I would involve site visits to determine such aspects as their condition, ownership, proximity to populated areas, prospects for increased population near the site, and need for corrective action. A preliminary report then would be prepared which would serve as a basis for determining if a detailed engineering assessment (Phase II) were necessary for each millsite. The Phase II study, if necessary, would include evaluation of the problems, examination of alternative solutions, preparation of cost estimates and of detailed plans and specifications for alternative remedial action measures. This part of the study would include physical measurements to determine exposure or potential exposure to the public.

The Phase I assessment began in May 1974, with teams consisting of representatives of the AEC, the EPA, and the states involved visiting 21 of the inactive sites. The Phase I report was presented to the JCAE in October 1974. Table 1-1 summarized the conditions at the time of the Phase I visits.[1] Based on the findings presented in the report, the decision was made to proceed with Phase II.

On May 5, 1975, ERDA, the successor to AEC, announced that Ford, Bacon & Davis Utah Inc. of Salt Lake City had been selected to provide the architect-engineering (A-E) services for Phase II. ERDA's Grand Junction, Colorado, office (GJO) was authorized to negotiate and administer the terms of a contract with FB&DU. The contract was effective on June 23, 1975. The Salt Lake City Vitro site was assigned as the initial task, and work began immediately. Field work at Naturita included gamma logging of tailings drill holes on March 10 and 11, 1976, field survey work from May 7 through May 11, 1976, and additional radon measurements on June 5 and 6, 1976, and October 7 through October 10, 1976.

1.1.2 Scope of Phase II Engineering Assessment

Phase II A-E Services are divided into two stages: Title I and Title II.

Title I services include the engineering assessment of existing conditions and the identification, evaluation and costing of alternative remedial actions for each site. Following the selection and funding of a specific remedial action plan, Title II services will be performed. These services will include the preparation of detailed plans and specifications for implementation of the selected remedial action.

This report is the assessment made for Title I requirements and was prepared by FB&DU. The Oak Ridge National Laboratory (ORNL) at Oak Ridge, Tennessee, under separate agreement with ERDA, provided measurements of the radioactivity concentrations in the soil and water samples and gamma surveys. The EPA staff provided the results of radiation surveys they previously had made at the Naturita site.

The specific scope requirements of the Title I assessment as given in the contract may include, but are not limited to the following:

(a) Preparation of an engineering assessment report for each site, and preparation of a comprehensive report suitable for submission to the Congress on reasonable remedial action alternatives and their estimated costs.

(b) Determination of property ownership in order to obtain release of federal government and A-E liability for performance of engineering assessment work at both inactive millsites and privately owned structures.

(c) Preparation of topographic maps of millsites and other sites to which tailings and other radioactive materials might be moved.

(d) Performance of core drillings and radiometric measurements ample to determine volumes of tailings and other radium-contaminated materials.

(e) Performance of radiometric surveys, as required, to determine areas and structures requiring cleanup or decontamination.

(f) Determination of the adequacy and the environmental suitability of sites to which mill tailings containing radium can be moved for long-term (>50 yr) storage; and once such sites are identified, perform evaluation and estimate the costs involved.

(g) Performance of engineering assessments of structures where uranium mill tailings have been used in off-site construction to arrive at recommendations and estimated costs of performing remedial action.

(h) Evaluation of various methods, techniques and materials for stabilizing uranium mill tailings to prevent wind and water erosion, to inhibit or eliminate radon exhalation, and to minimize maintenance and control costs.

(i) Evaluation of availability of suitable fill and stabilization cover materials that could be used.

(j) Evaluation of radiation exposures of individuals and nearby populations resulting from the inactive uranium millsite, with specific attention to:

(1) Gamma radiation

(2) Radon

(3) Radon daughter concentrations

(4) Radium and other naturally occurring radioisotopes in the tailings

(k) Investigation of site hydrology and meteorology.

(l) Evaluation of recovering residual values, such as uranium and vanadium in the tailings and other residues on the sites.

(m) Performance of demographic and land use studies. Investigation of community and area planning, and industrial growth projections.

(n) Evaluation of the alternative corrective actions for each site in order to arrive at recommendations, estimated costs, and socioeconomic impact based on population and land use projections.

(o) Preparation of preliminary plans, specifications, and cost estimates for alternative corrective actions for each site.

Not all of these items received attention at this site.

1.2 SITE DESCRIPTION

1.2.1 Location and Topography

The tailings site is located 2 mi northwest of the town of Naturita, Montrose County, Colorado in the San Miguel River Valley. The valley floor is at an elevation of approximately 5,355 ft above sea level. The locale is arid with canyons, mesas, steep cliffs and valleys which are typical of the western slope of the Rocky Mountains. The site and its relationship to the surrounding area is shown in the aerial photograph in Figure 2-1, Chapter 2.

1.2.2 Ownership and History of Milling Operations and Processing

The portion of the site occupied by the tailings was bought by Ranchers Exploration and Development Corporation of Albuquerque, New Mexico in 1976 from Foote Mineral Company. The balance of the site is owned by Foote Mineral Company, which has leased a portion to General Electric Company for an ore buying depot.

The mill was built in 1930 by the Rare Metals Company. It did not become operational until 1939, when Vanadium Corporation of America (VCA) acquired the mill and converted it to a salt-roast, water-leach process for vanadium recovery. The process was modified again in 1942 so that uranium could be extracted. Uranium concentrates were shipped to the AEC until 1958, when the mill was shut down. From 1961 until 1963 an upgrader was operated at the site by VCA. The mill was dismantled in 1963. In 1967, VCA was merged into Foote Mineral Company and site ownership passed to Foote.

During its life the mill processed 704,000 tons of ore. Prior to the 1958 shutdown the ore averaged 0.30% U_3O_8 and 1.8% V_2O_5. During the upgrader operation, ore averaging 0.25% U_3O_8 and 1.65% V_2O_5 was processed. Ore was received from throughout the Uravan mineral belt and beyond.

1.2.3 Present Condition of the Site

Figure 2-3, Chapter 2 is a descriptive map of a portion of the site as it now exists. The tailings pile is convex-shaped and covers about 23 acres. Figure 2-4, Chapter 2 is a typical cross-section of the site. The old mill building has been removed, although 17 buildings remain which are used for storage, office space, and by those leasing portions of the site as an ore buying station. The tailings were stabilized in 1969 with approximately 6 in. of earth cover. They now show signs of the erosive action of storms. Vegetation cover is approximately 40%. The site is fenced with a variety of fence types and is posted. There is a partial dike on the site between the tailings and the river. Maintenance and security are provided by the owners.

1.2.4 Tailings and Soil Characteristics

The tailings are mostly fine-grained sand with very little slime. Bulk densities average 111 lb/ft^3. There are approximately 704,000 tons of tailings on the site. The weight and volumes of tailings materials are given in Table 2-1, Chapter 2. The soil beneath the pile is composed of alluvial deposits of the San Miguel River.

1.2.5 Geology, Hydrology, and Meteorology

The Naturita site is located on the west bank of the modern flood plain of the San Miguel River, which flows northwestward through the narrow San Miguel River Valley. The tailings lie on approximately 50 ft of alluvium which overlies the shales, sandstones and conglomerates of the Brushy Basin Member of the Morrison Formation. The bedrock strata dip 2 to 4 deg northeastward. The Brushy Basin Member is 100 to 200 ft thick beneath the tailings and is underlain by the sandstones and shales of the Salt Wash Member of the Morrison Formation and the mudstones of the Summerville Formation. A simplified stratigraphic column is shown in Figure 2-5, Chapter 2.

The flowing surface waters adjacent to or near the site consist of the San Miguel River and intermittant streams that drain the neighboring canyons. One of these streams is diverted around the pile, but cloudbursts up the canyon have resulted in the flow of water across the northwestern portion of the pile. Waters have flowed onto the pile from the diversion ditch along the southwestern border of the site and from drainage at the northwest of the site. An intermediate regional flood (100-yr flood) of the San Miguel River or more severe floods would top the riprap protecting the pile and erode cover materials and tailings from the pile. Before the riprap protection was constructed, tailings were eroded from the pile.

The unconfined aquifers in the San Miguel River Valley consist of waters within the recent valley alluvium. Except during flooding season, the water table lies 3 to 10 ft below the tailings-subsoil interface. During an intermediate regional flood or more severe floods, the water table would rise within the alluvium and tailings. Ground waters flowing through the tailings during flood stages, and ground waters at normal levels can be contaminated by precipitation, ponded waters, and flood waters leaching through the pile.

Very little work has been done to identify confined ground water aquifers in the Naturita area. Potential aquifers consist of sandstone strata within the Morrison Formation, and the sandstone units within the Entrada Formation. The Summerville Formation separates the Morrison Formation from the Entrada Formation and prevents downward migration of water. The Morrison Formation is the host rock for much of the uranium ore in the area and is not tapped as an aquifer. It is recharged in the Naturita area and the hydraulic flow gradient is to the northeast of the pile.

Meteorological records from the Hopkins-Montrose Airport, which lies 2.5 mi east of the site but outside the San Miguel River Valley, show that thunderstorm activity and precipitation in the area can be expected from May through October. Average annual precipitation at Naturita totals about 11 in. Cloudbursts at the site or in the canyons above the site have resulted in physical erosion of the tailings. The strongest winds at the site are those that are channeled up and down the canyon.

1.3 RADIOACTIVITY AND POLLUTANT IMPACTS ON THE ENVIRONMENT

About 85% of the total radioactivity originally in uranium ore remains in the tailings after removal of the uranium because the radium and thorium, principal contributors to radioactive emissions, were not normally removed from the uranium ores during milling. The principal environmental radiological impact and associated health effects arise from the ^{230}Th, ^{226}Ra, ^{222}Rn, and ^{222}Rn daughters contained in the uranium tailings. Although these radionuclides occur in nature, their concentrations in tailings materials are several orders of magnitude greater than their average concentrations in the earth's crust.

1.3.1 Radiation Exposure Pathways, Contamination Mechanisms, and Background Levels

The major potential environmental routes of exposure to man are:

(a) Inhalation of ^{222}Rn and its daughter products, resulting from the continuous radioactive decay of ^{226}Ra in the tailings. Radon is a gas which diffuses from the piles. The principal exposure results from inhalation of the ^{222}Rn and Rn daughters. This exposure affects the lungs. For this assessment, no criteria have been established for radon concentrations in air. However, the pathway for radon and radon daughters accounts for the major portion of the exposure to the population.

(b) External whole-body gamma exposure directly from radionuclides in the pile.

(c) Inhalation and ingestion of windblown tailings. The primary health effect relates to the alpha emitters ^{230}Th and ^{226}Ra, each of which causes exposure to the bones and lungs.

(d) Ingestion of ground and surface water contaminated with radioactive elements (primarily ^{226}Ra) and other toxic materials.

(e) Contamination of food through uptake and concentration of radioactive elements by plants and animals is another pathway which can occur; however, this pathway was not considered in this study.

1.3.1.1 Radon Gas Diffusion and Transport

Short-term radon measurements were performed with the ERDA-supplied continuous radon monitors at 11 locations in the vicinity of the Naturita tailings pile. The locations and values of the radon measurements are shown in Figure 3-3, Chapter 3. The highest outdoor radon concentration off the pile was measured 0.17 mi north of the Naturita site in the San Miguel River Valley. The radon concentration including background at this location averaged 15.0 pCi/l for a 24-hr period. Indoor radon concentration averaged 7.7 pCi/l at the Foote Mineral Company office 0.11 mi south of the pile.

Five 24-hr measurements of atmospheric radon indicated an average background concentration of 2.0 pCi/l for the Naturita area.

1.3.1.2 Direct Gamma Radiation

The range of natural background values in the Naturita area was between 7 and 12 μR/hr, averaging 10 μR/hr as measured 3 ft above ground with an energy-compensated Geiger Mueller detector.(2) Above the surface of the tailings pile, gross gamma radiation rates were measured as high as 780 μR/hr. Across the road at the former ore stockpile area, gamma radiation reached a maximum of 380 μR/hr.

1.3.1.3 Windblown Contaminants

Prevailing winds in the area follow the San Miguel River Valley and therefore tend to be northwest and southeast winds. Concentrations of ^{226}Ra in surface soil samples and the EPA gamma survey were used to determine the extent of windblown tailings. Gamma radiation surveys indicate windblown tailings as far as 0.7 mi to the northwest of the Naturita tailings pile. Iso-exposure lines due to residual windblown tailings are illustrated in Figure 3-10, Chapter 3.

1.3.1.4 Ground and Surface Water Contamination

Three water samples taken from the San Miguel River during this assessment contained ^{226}Ra concentrations ranging from 0.4 to 1.7 pCi/l.(2) These samples appeared to indicate a small, localized contamination of the San Miguel River immediately adjacent to the tailings pile; however, these values are less than the EPA Interim Drinking Water Regulation for radionuclides.(3)

1.3.1.5 Soil Contamination

The leaching of radium from the tailings extends into the subsoil an average of 5 ft before reaching the twice average background radium concentration in the soil (1.5 pCi/g). The range of contamination is from 3 to 6 ft beneath the tailings-subsoil interface.

1.3.2 Remedial Action Criteria

Radiological criteria established for this engineering assessment are divided into two general categories:

(a) Criteria applicable to structures with tailings underneath them or within 10 ft

(b) Criteria pertaining to the mill tailings site and open land

The criteria utilized for habitable structures are the guidelines published by the Surgeon General of the United States for use in the Grand Junction, Colorado, remedial program. These guidelines recommend graded levels (based on yearly average values) for remedial action in terms of the external gamma radiation (EGR) levels and of the indoor radon daughter concentration (RDC) levels above background found within dwellings constructed on or near uranium mill tailings. (In this usage, the word "external" refers to gamma radiation from sources outside the human body to which an individual may be exposed.)

The recommended graded levels are as follows:

EGR	RDC[a]	Recommendations
Greater than 0.1 mR/hr[b]	Greater than 0.05 WL[c]	Remedial action indicated
From 0.05 to 0.1 mR/hr	From 0.01 to 0.05 WL	Remedial action may be suggested
Less than 0.05 mR/hr	Less than 0.01 WL	No remedial action indicated

[a]Based upon yearly average values from six air samples of at least 100-hr duration taken at a minimum of 4-wk intervals throughout the year
[b]mR/hr = milliroentgen per hour, a measure of gamma radiation, 1 mR/hr = 1,000 μR/hr
[c]WL = working level, a measure of alpha radiation from short-lived radon daughter elements

The criteria for land decontamination have the objective of reducing residual gamma radiation to levels which are as low as practicable. However, topographic and economic considerations frequently preclude complete decontamination. A provisional maximum of 40 μR/hr above background is used in such circumstances. Average background in the Naturita area was determined in this study to be 10 μR/hr. As a guideline for the land beyond the site, if residual gamma levels are less than 10 μR/hr above background, the land may be released for unrestricted use. Where cleanup is necessary the radium content of the soil should be reduced to no more than twice the radium background in the area. If the radioactive tailings material is stabilized in place, the same criteria apply but control of gamma radiation would be by an earth covering. However, the area should be designated a controlled area, be fenced to limit access, and be restricted as to human occupancy. The numerical guidelines provide a basis for the engineering assessment, but are subject to review based on the overall findings of Phase II.

The ^{226}Ra content of ground and surface water should meet applicable state and federal standards.

1.3.3 Potential Health Impact

The gamma radiation levels are in the background range within 0.2 mi from the pile, except in the north-northwest direction in which the gamma radiation is still twice background 0.8 mi from the pile; however, there are no inhabitants in this direction.

The gamma exposure and the inhalation of radon daughters from the tailings pile under present conditions account for almost all of the dose derived from the tailings to the people living in the Naturita area at the present time. It is very difficult to control the movement of radon gas through porous solid cover matetials. Once released from the radium-bearing minerals in the tailings, the gaseous radon diffuses by the path of least resistance to the surface. The radon has a half-life of about 4 days, and its daughter products are solids. Therefore, part of the radon decays en route to the surface and leaves daughter products within the tailings piles. If the diffusion path can be made long enough, then, theoretically, substantially all the radon and its daughter products can be made to decay before escaping to the atmosphere. Calculations using the techniques of Kraner, Schroeder, and Evans(4) indicate that 13 ft of earth cover theoretically would be required to reduce the radon diffusion from the Naturita tailings by 95%.

The health significance to man of long-term exposure to radiation is a subject that has been studied extensively for many years. Since the end results of long-term exposure to low-level radiation are usually diseases such as lung cancer or leukemia, which also are attributable to many other causes, the determination of specific cause in any given case becomes very difficult. Therefore, the usual approach to evaluation of the health impact of low-level radiation exposures is to make projections from observed effects of high exposures on the premise that the effects are linear. A considerable amount of information has been accumulated on the high incidence of lung cancer in uranium miners exposed to radon and its daughters in mine air. This provides a basis for calculating the probable health effects of low-level exposure to large populations. (The term "health effect" refers to an incidence of disease; for radon daughter exposure, 1 health effect = 1 case of lung cancer.) This is the basis of the health effects calculations in this report. It should be recognized, however, that there is a large degree of uncertainty in such projections. Among the complicating factors is the combined effect of radon daughters with other carcinogens. As an example, the incidence of lung cancer among uranium miners who smoke is far higher than can be explained on the basis of either smoking or the radiation alone.

The risk estimators used in this report are given in the report of the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR report).(5) This report presents risk estimators for lung cancer derived from epidemiological studies of both uranium miners and fluorspar miners. The average of the absolute risk estimator for these two groups is: 6 cancers per year per 10^6 person-WLM exposure. The term WLM means working level month, or an exposure to a concentration of one working level of radon daughter products in air for 170 hr, which is a work-month. A working level (WL) is a unit of measure of radon daughter products which recognizes that the several daughter elements are frequently not in equilibrium with each other nor with the parent radon. Because of the many factors which contribute to natural biological variability, and of the many differences between exposure conditions in mines and residences, this estimator (6 cancer cases per year per 10^6 person-WLM) is considered to have an uncertainty factor of about 3. The relative risk estimator can be several factors larger than the absolute risk estimator.[6]

For the purpose of the mill tailings assessment, it was assumed that about 50% equilibrium exists inside structures between radon and its daughter elements resulting in the following conversion factors:

$$1 \text{ pCi/l of } ^{222}\text{Rn} = 0.005 \text{ WL}$$

For continuous exposure:

$$0.005 \text{ WL} = 0.25 \text{ WLM/yr}$$

On the basis of measurements and predictions of radon concentrations in excess of background values, it is caluclated that the average pile radon-induced lung cancer risk to the population in the area within 4 mi from the Naturita tailings site is 2×10^{-6} per person per year, or about 4×10^{-3} health effects per year in the area. The health effect rate for background radon is approximately 8.9×10^{-5} per person per year, or about 0.17 effects per year in the area. The average cancer risk due to all causes for Colorado residents is 1.8×10^{-4} per person per year.[7] Within 4 mi of the pile the average lung cancer risk due to the pile is about 1% of the cancer risk due to all causes.

The cumulative health effects over a 25-yr period were calculated for three population projections. The results are as follows:

25-yr Cumulative Health Effects 0-4 Mi from Edge of Pile

Projected Population Growth	Pile-Induced RDC	Background RDC
Static population	0.10	4.3
2% annual population growth[a]	0.12	5.1
4% annual population growth[a]	0.14	6.1

[a]The growth rate decreases linearly with time to zero in 25 yr.

As a result of the low population density, the low radiation levels of the tailings at the Naturita site, and the relatively high background radon levels, the potential health impact of the pile is minimal for persons not working or living directly on or adjacent to the site.

1.3.4 Nonradioactive Pollutants

There are other potentially toxic materials in the tailings. Chemical analyses of tailings samples from drill holes on the Naturita tailings pile showed selenium at about 0.5 ppm, lead and arsenic between 40 and 60 ppm, and chromium concentration up to 3.5 ppm. Three samples of surface waters in the area surrounding the Naturita tailings pile containing selenium in concentrations above the EPA Interim Drinking Water Standards. The selenium content of the San Miguel River increased about 30% as it passed the Naturita tailings pile to about 1.2 times the EPA standard of 0.01 mg/l. San Miguel River samples both up and downstream contained chromium at or above the EPA standard for drinking water. However, standing water which had flowed off the tailings did not contain any measurable chromium.

1.4 SOCIOECONOMIC AND LAND USE IMPACTS

Based on site inspection and census records, 18,366 persons are assumed as the 1970 population base of Montrose County, and 1,914 persons are assumed to be living within 4 mi of the pile. Calculations of population projection could be misleading because of the area's small population base and its extreme dependence on mining. The limited water supply, lack of potential for tourism, and isolation of the area make sustained population expansion unlikely.

Virtually all the land near the tailings pile is devoted to low density grazing and other agricultural uses. Three residential communities are within a 5-mi radius of the pile, East Vancorum, West Vancorum and Naturita. There are 34 occupied units at West Vancorum, 4 occupied units at East Vancorum, and unoccupied units and trailer sites at both locations. The nearest commercial activity is at Naturita.

The assessed values of the properties near the site range from $7.59/acre to $8.33/acre, including improvements. The Foote Mineral Company property is listed at $28,533.33 with improvements. The presence of the tailings restricts the use of the tailings area itself. However, the loss of grazing or crop land is minimal and the presence of the tailings has not affected the land use or values of surrounding property. In general, the land surrounding the site has a market value of about $1,000/acre.

1.5 RECOVERY OF RESIDUAL VALUES

Samples of tailings obtained during this study were composited and analyzed. Data obtained from the AEC indicated the Naturita pile contains 0.047% U_3O_8. Using the AEC estimate, the Naturita tailings contain 662,000 lb of U_3O_8.

There are five factors that should be employed to evaluate whether reprocessing the Naturita tailings to extract residual uranium and other mineral values would be practicable:

(a) The amount of tailings present

(b) Concentrations of residual values

(c) Projected recovery

(d) Current market price of recovered values

(e) Proximity to processing mills

Based on the aforementioned criteria, reprocessing of the Naturita tailings is economically attractive at this time.

1.6 MILL TAILINGS STABILIZATION

Present practices and technology of mill tailings stabilization are being examined. This investigation indicates that much research and development remains to be performed before complete and permanent stabilization of radioactive mill tailings can be realized.

Reasonably effective means of wind and water erosion control are available, although they will involve continued maintenance costs. Lining of containment areas or chemical solidification of the tailings are possible methods for control of leaching.

Up to this time, no attempt has been made to contain radon in a tailings pile. Although a thick earth cover is theoretically effective, it has not actually been tried. The observed variability of radon exhalation rates indicates that with better understanding of the mechanism involved, control may be possible.

The existing cover and vegetation on the Naturita tailings have reduced tailings erosion from wind and rainfall and have provided partial control over gamma radiation, but little control over radon exhalation. A vegetative cover has been established on the Naturita tailings.

1.7 REMEDIAL ACTIONS AND BENEFITS

Two closely related objectives of this engineering assessment are to identify those structures and land areas off site where tailings are located and, based upon the Surgeon General's guidelines and on criteria established for this assessment, to estimate the costs of appropriate remedial actions. Some tailings have been transported off the site by individuals, and some by wind and water erosion.

The remedial options at the Naturita site are limited as a result of unique conditions existing there. Ranchers Exploration and Development Company is responsible for removing contaminated soil beneath the pile under the State of Colorado license that was granted to Ranchers for reprocessing the tailings. Thus, remedial action options need not consider decontamination of the present tailings area. However, measurements of the extent of subsoil contamination have been made and are shown in Figure 7-1, Chapter 7. Also given in the figure are the estimated costs per foot to remove the contaminated subsoil. The southeastern portion of the site is under lease to General Electric Company and currently contains an active ore storage area. Therefore, decontamination of this area is not possible.

Given these conditions, two alternative remedial action options were formulated to include decontamination of off-site structures and windblown areas adjacent to the tailings site. Costs are also identified for removal of the tailings and contaminated subsoil to another location.

1.7.1 Remedial Action for Structures (Option I)

This option includes millsite building decontamination and remedial action at off-site structures where tailings have been identified. A mobile scanning unit, operated by the AEC under an interagency agreement with EPA, performed gamma radiation surveys of the Naturita and Nucla, Colorado areas in 1971. Follow-up gamma surveys of the 33 anomalies at Naturita and the 13 anomalies at Nucla found 10 tailings use locations in Naturita and 3 in Nucla.

The cost for remedial actions at these structures under Option I is estimated at $270,000.

An extended series of measurements, such as required in the full application of the Grand Junction Remedial Action Criteria, might reduce the actual number of locations included in the remedial action. The locations at which tailings are on vacant lands or are greater than 10 ft from structures were not subject to the criteria used in Phase II, but could constitute a problem in the future.

1.7.2 Remedial Action for Open Lands (Option II)

Option II includes cleanup of windblown contamination adjacent to the tailings site in addition to the remedial actions for structures that constitute Option I. The extent of windblown tailings is illustrated in Figure 3-10, Chapter 3. The area to be decontaminated under this option is shown in Figure 7-2, Chapter 7. The ore buying station on the millsite and ore storage areas are not included in the decontamination effort because they are currently in use.

The cost of Option II is estimated at $950,000. The costs for moving the tailings and contaminated soil to another location 5 mi away, including site preparation, 2 ft of cover on the tailings after placement, fencing, and an endowment fund for annual maintenance are $4,500,000.

1.7.3 Benefits

Option II and the Ranchers Exploration decontamination beneath the tailings would leave the site in a condition suitable for unrestricted use; however, the presence of the ore stockpile and ore buying station would restrict activities at the site.

Health effects from the Naturita tailings are negligible in their present location and therefore no cost benefit analysis was performed. Generally, remedial action on structures (Option I) has a very favorable health benefit-to-cost ratio.

Land value of the tailings area could increase from a current estimated \$200/acre to a possible \$1,000/acre for a net increase of \$18,400 for the 23 acres.

TABLE 1-1

SUMMARY OF CONDITIONS NOTED AT TIME OF PHASE I SITE VISITS [a]

	Cond. of Tailings	Cond. of Structures on Site	Mill Housing	Adequate Fencing, Posting, Security	Property Close by River or Stream	Houses-Industry w/in 1/2 Mile	Evidence of Wind Water Erosion	Possible Water Contamination	Tailings Removed for Private Use	Other Hazards On-site
<u>ARIZONA</u>										
Monument	U	R	N	No	No	Yes	No	No	No	No
Tuba City	U	PR-UO	E-O	No	No	Yes	Yes	No	No	Yes
<u>COLORADO</u>										
Durango	P	PR-UO	N	Yes	Yes	Yes	Yes	No	Yes	Yes
Grand Junction	S	PR-O	N	Yes	Yes	Yes	No	No	Yes	No
Gunnison	S	B-O	N	Yes	No	Yes	No	Yes	No	No
Maybell	S	R	N	Yes	No	No	No	No	No	No
Naturita	S	PR-O	E-P	Yes	Yes	No	Yes	Yes	No	No
New Rifle	P	M-O	N	Yes	Yes	Yes	Yes	Yes	No	No
Old Rifle	S	PR-UO	N	Yes	Yes	Yes	No	Yes	Yes	No
Slick Rock (NC)	S	R	N	No	Yes	Yes	Yes	No	No	No
Slick Rock (UCC)	S	R	E-P	Yes	Yes	Yes	No	No	No	No
<u>IDAHO</u>										
Lowman	U	R	N	No	Yes	Yes	No	No	Yes	No
<u>NEW MEXICO</u>										
Ambrosia Lake	U	PR-O	N	Yes	No	No	Yes	No	No	No
Shiprock	P	PR-O	E-O	Yes	Yes	Yes	No	No	Yes	Yes
<u>OREGON</u>										
Lakeview	U	M-UO	N	Yes	No	Yes	Yes	No	No	No
<u>TEXAS</u>										
Falls City	P	M-UO	N	Yes	No	No	No	No	No	No
Ray Point	P	M-UO	N	Yes	No	No	No	No	No	No

TABLE 1-1 (Cont)

	Cond. of Tailings	Cond. of Structures on Site	Mill Housing	Adequate Fencing, Posting, Security	Property Close by River or Stream	Houses-Industry w/in 1/2 Mile	Evidence of Wind Water Erosion	Possible Water Contami-nation	Tailings Removed for Pri-vate Use	Other Hazards On-site
UTAH										
Green River	S	B-O	N	Yes	No	Yes	Yes	Yes	No	No
Mexican Hat	U	B-O	E-O	No	No	Yes	Yes	Yes	No	No
Salt Lake City	U	R	N	No	Yes	Yes	Yes	Yes	Yes	Yes
WYOMING										
Converse County	U	R	N	No	No	No	No	No	No	No

(1) S - Stabilized but requires improvement

P - Partially stabilized

U - Unstabilized.

(2) M - Mill intact

B - Building(s) intact

R - Mill and/or buildings removed

PR- Mill and/or buildings partially removed

O - Occupied or used

UO- Unoccupied or unused.

(3) N - None

E - Existing

O - Occupied

P - Part occupied.

[a]This table does not necessarily represent conditions at the present time.

TABLE 1-2

SUMMARY OF REMEDIAL ACTION OPTIONS AND EFFECTS

Option Number	Cost[1] ($000)	Description of Remedial Action[2]	Benefits	Adverse Effects
I	270	Off-site remedial action for structures in Naturita and Nucla	A,B,C,E, G	H
II	950	Off-site remedial action for windblown tailings and off-site remedial action for structures	A,B,C,D,E F,G	

Notes

1. Costs are in 1977-value dollars.
2. Assumes tailings will be removed from present site for reprocessing.

Definition of Benefits

A. Gamma radiation from pile eliminated.
B. Radon exhalation greatly reduced.
C. Wind and water erosion of tailings eliminated, no maintenance required.
D. Windblown tailings removed.
E. Tailings site available for limited use.
F. Tailings site and area NW of tailings available for limited use.
G. Reduction of exposure to individuals in off-site structures.

Definition of Adverse Effects

H. No reduction in gamma radiation and radon exhalation from windblown tailings.

CHAPTER 1 REFERENCES

1. "Summary Report, Phase I Study of Inactive Uranium Mill Sites and Tailings Piles"; AEC; Grand Junction, Colorado; Oct 1974.

2. F. F. Haywood, et al; "Assessment of Radiological Impact of the Inactive Uranium Mill Tailings Pile at Naturita, Colorado"; ORNL (in preparation).

3. Federal Register, Part II; EPA-Drinking Water Regulations; EPA; Jul 9, 1976.

4. H. W. Kraner, G. L. Schroeder, and R. D. Evans; "Measurements of the Effects of Atmospheric Variables on Radon-222 Flux and Soil-Gas Concentrations"; The Natural Radiation Environment; J. A. S. Adams and W. M. Lowder, eds; University of Chicago Press; 1964.

5. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation"; Report of Advisory Committee on Biological Effects of Ionizing Radiation; NAS; National Research Council; Nov 1972.

6. "Health Effects of Alpha-Emitting Particles in the Respiratory Tract"; Report of the Advisory Committee on the Biological Effects of Ionizing Radiation; EPA/ORP; EPA-520/4-76-013; Washington, D.C.; Oct 1976.

CHAPTER 2

SITE DESCRIPTION

CHAPTER 2

SITE DESCRIPTION

The purpose of this chapter is to describe the Naturita site and the characteristics of the tailings materials present on the site.

2.1 LOCATION

The Naturita mill and tailings are located in the narrow San Miguel River Valley 2 mi northwest of the town of Naturita in Montrose County, Colorado, as shown in Figure 2-1. The site occupies parts of Sections 14 and 15, Township 46 North, Range 16 West, New Mexico Principal Meridian, at 38 deg 14 min 30 sec north latitude and 108 deg 36 min 0 sec west longitude.

2.2 TOPOGRAPHY

The site is located on the San Miguel River Valley floor on the west side of the San Miguel River. This location is within the canyonlands area of the Colorado Plateau on the western slope of the Rocky Mountains. The area is typified by relatively smooth, sloping surfaces broken by canyons with rough and precipitous topographic relief. The canyon floor varies in elevations from 5,350 ft to 5,360 ft through the site area. Canyon walls and mesas rise on both sides to elevations of 6,250 ft. Vegetation is sparse in the area and varies widely, depending upon elevation and proximity to a water supply. Juniper, pinion pine, and sagebrush grow in the canyon and on the mesas. Willows, native grasses, and cottonwoods grow near the river.

The millsite occupies approximately 86 acres and the tailings cover about 23 acres between Colorado Highway 141 and the San Miguel River. Figure 2-2 shows a topographic map of the tailings area.

2.3 OWNERSHIP

In November 1976, Ranchers Exploration and Development Corporation of Albuquerque, New Mexico obtained ownership of approximately 24 acres containing the tailings. The former owner of the tailings area and the current owner of the remainder of the site is the Foote Mineral Company, which was formed as a result of a merger in 1967 between Vanadium Corporation of America (VCA) and Foote. The Rare Metals Company, the original owner, sold the site in 1939 to the VCA.

2.4 HISTORY OF MILLING OPERATIONS AND PROCESSING[1]

The Naturita mill was built about 1930, but did not become

[1] See end of chapter for references.

operational until it was purchased and modified by VCA in 1939 to use a salt-roast water-leach process for vanadium recovery.[2] Process water was obtained from the San Miguel River. In 1942, the plant process was modified again so that uranium as well as vanadium could be extracted. At the end of World War II, the mill was shut down. The VCA at Naturita was the first company awarded a contract by the Atomic Energy Commission under the uranium procurement program, and initial shipments of uranium concentrates to the AEC began in 1947. The VCA continued this operation until 1958, when the mill was shut down. From late 1961 to early 1963, VCA operated an upgrader plant at the site.[2] The mill was shut down and dismantled in 1963, and all the equipment was decontaminated. Because of extensive contamination, the tailings launder was buried within the tailings pile. During the period 1947 to 1963, the Naturita mill processed 704,000 tons of uranium-vanadium ore.

The ore processed at the Naturita mill until shutdown in 1958 averaged 0.30% U_3O_8 and 1.80% V_2O_5. Ores averaging 0.25% U_3O_8 and 1.65% V_2O_5 were processed at the upgrader from 1961 to 1963 and the upgraded material was shipped to Durango, Colorado for further processing. These ores came from within the Uravan Mineral Belt and from as far west as the Cottonwood Wash in Utah. The mill owners processed ore from independent operators as well as from company-controlled properties. All ore was trucked to the Naturita mill.

2.5 PRESENT CONDITION OF THE SITE

The tailings are in one large convex-shaped pile. The slopes are gentle, about a 2.5-to-1 rise, and slope towards the San Miguel River on the east and Colorado Highway 141 on the west.

Seventeen buildings remain on the old millsite. Most could be classified as sheds; although there is an office building, a garage, and a warehouse. All the buildings are used either for storage purposes by Foote Mineral Company or by General Electric Company, which leases some of the facilities to accommodate an ore buying activity. The current general layout of the site, facilities, and tailings are shown in the descriptive map of Figure 2-3, and in a cross-section shown in Figure 2-4.

In accordance with plans prepared by Foote Mineral Company and approved by the Colorado Department of Health, the tailings were stabilized in the fall of 1969 and the winter of 1970. At that time the pile was covered with a minimum of 6 in. of topsoil, was fertilized and seeded, and a sprinkler system was installed. The pile was sprinkled for 1 yr until the vegetation root system was established. The irrigation system still exists but is inoperative. The stabilization cover was insufficient to prevent water erosion of the pile. An unusually heavy rainfall which occurred in July 1973 washed much of the stabilization cover and some of the tailings from the upper portion onto the lower portion of the pile against a dike which separates the pile from the river. Some parts of the dike were breached. Some tailings have been pushed back onto the pile from the bank of the San Miguel River, and rock material has been used to strengthen the dike along the northeast (downriver) face of the pile near the river. The site and tailings are fenced, mostly with barbed wire fencing.

2.6 TAILINGS AND SOIL CHARACTERISTICS

The tailings appear to be mostly finely ground sand, with very little clay.(3) The east end of the pile, which was used as a waste pond for alumina sludge is spongy and contains considerable moisture. Table 2-1 is a summary of the types, weights, and volumes of materials present on the site. The physical properties and pH of a soil sample from auger hole NC-2 are given in Table 2-2. The bulk density is 111 lb/ft^3 and the pH is in the neutral range. Assays of composite tailings samples are shown in Table 2-3.

The tailings are located on the modern flood plain of the San Miguel River. There is a fine reddish-brown sand beneath the tailings. These alluvial deposits below the tailings, perhaps as thick as 50 ft, consist of coarse and poorly sorted gravels, sands, and cobbles. Underlying this alluvium are shales of the Brushy Basin Member of the Morrison Formation.

2.7 GEOLOGY, HYDROLOGY, AND METEOROLOGY

2.7.1 Geology

The Naturita site is located on the west bank of the modern flood plain of the San Miguel River which flows northwestward through the narrow San Miguel Canyon. The river-run alluvium of the flood plain overlies the shales, sandstones, and conglomerates of the Brushy Basin Member of the Morrison Formation. The surrounding cliffs and mesas are formed by the sandstones and conglomerates of the Burro Canyon Formation. The strata of the Brushy Basin Member were laid down by rivers and in lakes during Jurassic time. The shale beds within the formation act as partial barriers to the upward and downward migration of ground waters, but the sandstones and conglomerates are aquifers and are recharged by the flow of surface waters across them.

At the millsite the strata dip 2 to 5 deg northeast. The Brushy Basin Member is 100 to 200 ft thick beneath the tailings and underlain by the sandstones and shales of the Salt Wash Member of the Morrison Formation and the mudstones of the Summerville Formation. A simplified stratigraphic column of the rock formations is shown in Figure 2-5.

2.7.2 Surface Water Hydrology

As shown in Figure 2-6, the flowing surface waters near the site consist of the San Miguel River to the northeast and an intermittant stream which drains the watershed west and northwest of the tailings. This stream enters the river 200 ft downstream of the tailings. Another intermittant stream drains the canyon south of the tailings, and crosses beneath Colorado Highway 141 via a 30-in. corrugated metal culvert. This stream is directed to the west by an earthen dike which intersects an old irrigation ditch. This ditch proceeds to the west, crosses back under the highway then parallels the highway to where it intersects a natural drainage channel immediately northwest of the pile. During severe runoff conditions, such as after a thunderstorm, canyon drainage is not diverted to the west at Highway 141 but crosses onto the millsite and flows northeast across the property into the San Miguel River. The ditch which bounds the southwestern side of the pile has been breached in two places and has allowed waters to flow onto the pile. Water also has flowed across the northwestern corner of the pile and has collected on the northern edge of the pile near the river.

The San Miguel River originates in the San Juan Mountains near Telluride and drops rapidly to its confluence with the Dolores River 20 mi downstream from Naturita. In the vicinity of the pile, the river is contained within a relatively narrow canyon on a 400-ft-wide flood plain which has been narrowed to 100 ft by the pile. The northeastern edge of the pile parallels the river. At the closest, the pile lies within 15 ft of the river bank and at most lies 50 ft from it. The slope of the pile rises gently 40 ft to the base of the highway to the west of the pile. There is no flood plain along the eastern bank of the river. An intermediate regional flood (100-yr flood) and more severe floods would inundate the tailings.(1,4) Riprap protects the tailings to a river crest of 6 ft, but a peak stage height of 13 ft is projected for the river at the tailings area. In addition, the artificial narrowing of the flood plain will cause flow velocities to be two to four times faster than up or downstream from the pile. Flood waters removed tailings materials from the site before the riprap barrier was established along the river bank.

Contamination of surface waters near the pile could occur by physical transport of the tailings by overland runoff and by seepage through the pile. Although most of the pile is stabilized, gullies have developed in portions of the pile and tailings have been carried north off the site. The ditch to the southwest of the pile is only partially effective in stemming the flow of offsite runoff onto the site. Water can pond near the northernmost section of the pile and could seep into the pile.

2.7.3 Ground Water Hydrology

The tailings lie on alluvium of the San Miguel flood plain separated by approximately 50 ft from the strata of the Brushy Basin Member of the Morrison Formation. Very little work has been done to identify confined ground water aquifers in the

Naturita area. Potential aquifers consist of the sandstone lenses within the Brushy Basin and Salt Wash Members of the Morrison Formation, and the sandstones of the Entrada Formation which are approximately 500 ft below the pile. These aquifers are recharged by precipitation and by surface waters as they flow across outcrops. The general gradient of confined ground water flow is to the northeast of the pile. Thus, the aquifers of the Morrison Formation are recharged in the Naturita area. The Summerville Formation separates the Morrison Formation from the Entrada Formation and prevents downward migration of waters. The Morrison Formation is the host rock for much of the uranium mining in the area and is not tapped as an aquifer.

The unconfined aquifers in the Naturita area consist of waters within the flood plain deposits. Except during flooding season the water table lies 3 to 10 ft below the tailings-subsoil interface. During an intermediate regional flood or a more severe flood, the water table would rise within the alluvium and tailings. Ground waters flowing through the tailings during flood stages, and ground waters at normal levels could be contaminated by waters leaching through the pile. The disposal area for the slimes within the southern corner of the site has never totally dried out.

Within a 2-mi radius of the tailings there are four wells as shown in Figure 2-7. The three alluvial wells are all hydraulically upgradient of the pile and there is no potential for contaminating these wells or the bedrock well. Any migration of contaminants would be downstream and downgradient from the pile or in confined aquifers northeast of the pile. The Naturita sewage plant is located adjacent to the San Miguel River between the town and the tailings and would further discourage use of water at the pile for domestic purposes. Downstream from the pile, river water is used for irrigation; further downstream, river water is used for culinary purposes at isolated farm houses.

2.7.4 Meteorology

High-intensity rainfall such as thunderstorms can be expected in the Naturita area. These storms have caused physical erosion of the tailings. Average annual precipitation at Naturita totals about 11 in. Large rainstorms occur usually from May through October. A rainfall of 6-hr duration totalling 1.1 in. has a probability of occurring once in five seasons.[5] A high-intensity cloudburst at the site in the canyons above the site would result in erosion of cover and tailings materials.

Very little direct information exists regarding the frequency, duration, and intensities of winds in the immediate vicinity of the tailings. The weather data for the area have been gathered at the Hopkins-Montrose County Airport 2.5 mi west of the site and north of the narrow valley which controls the winds at Naturita. The strongest winds are those which blow up or down the valley as depicted in Figure 2-8. A wind rose from the Hopkins-Montrose County Airport is given in Figure 2-9. The wind records from the airport indicate a predominance of winds from the southwest quadrant. Valley winds tend to carry material northwest and, to a lesser extent, southeast of the site.

FIGURE 2-1 AERIAL PHOTOGRAPH OF SITE

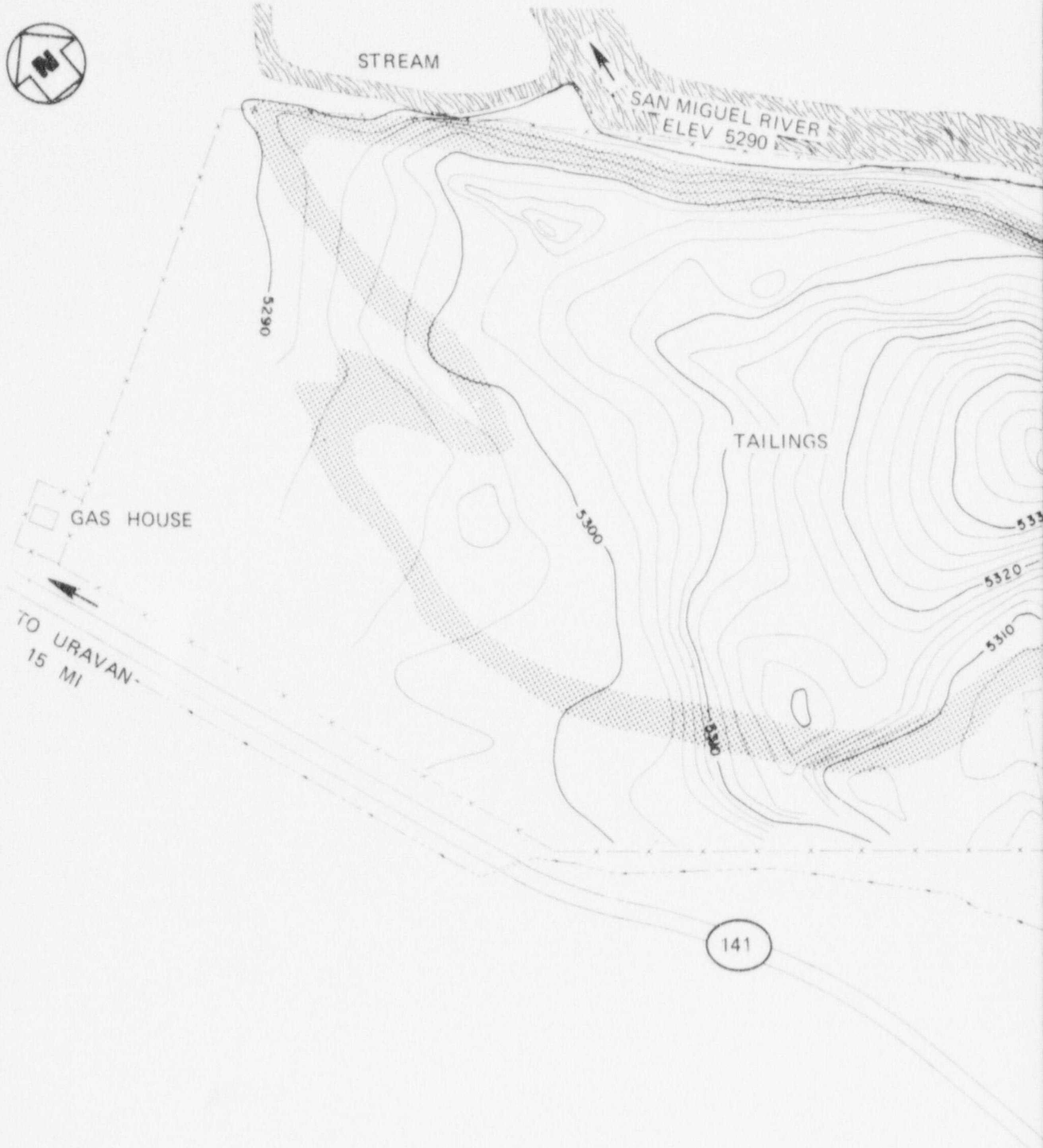
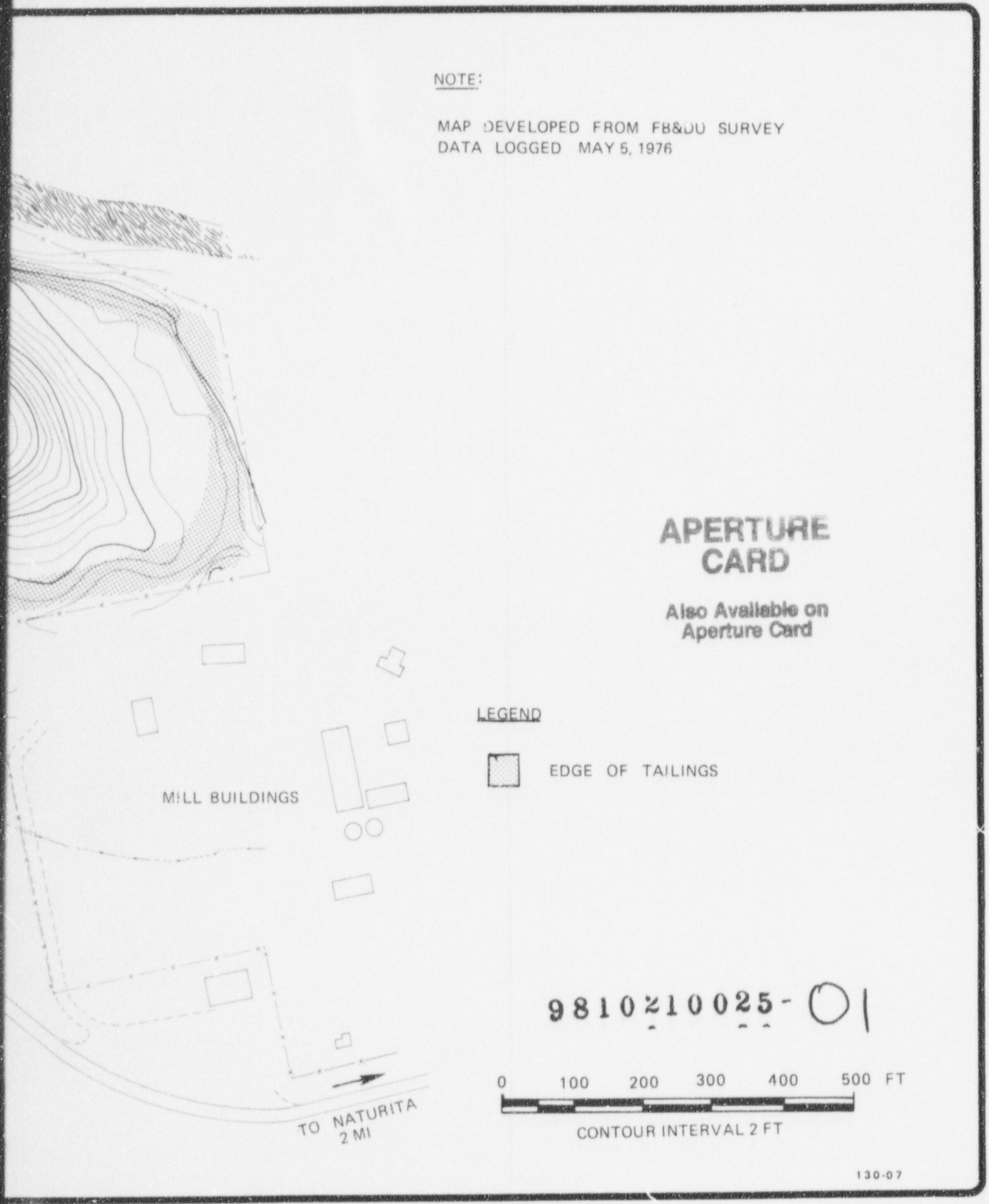


FIGURE 2–2. TOPOGRAPHIC MAP


NOTE:
MAP DEVELOPED FROM FB&DU SURVEY
DATA LOGGED MAY 5, 1976
MILL BUILDINGS
LEGEND
EDGE OF TAILINGS
TO NATURITA
2 MI
0 100 200 300 400 500 FT
CONTOUR INTERVAL 2 FT
130-07

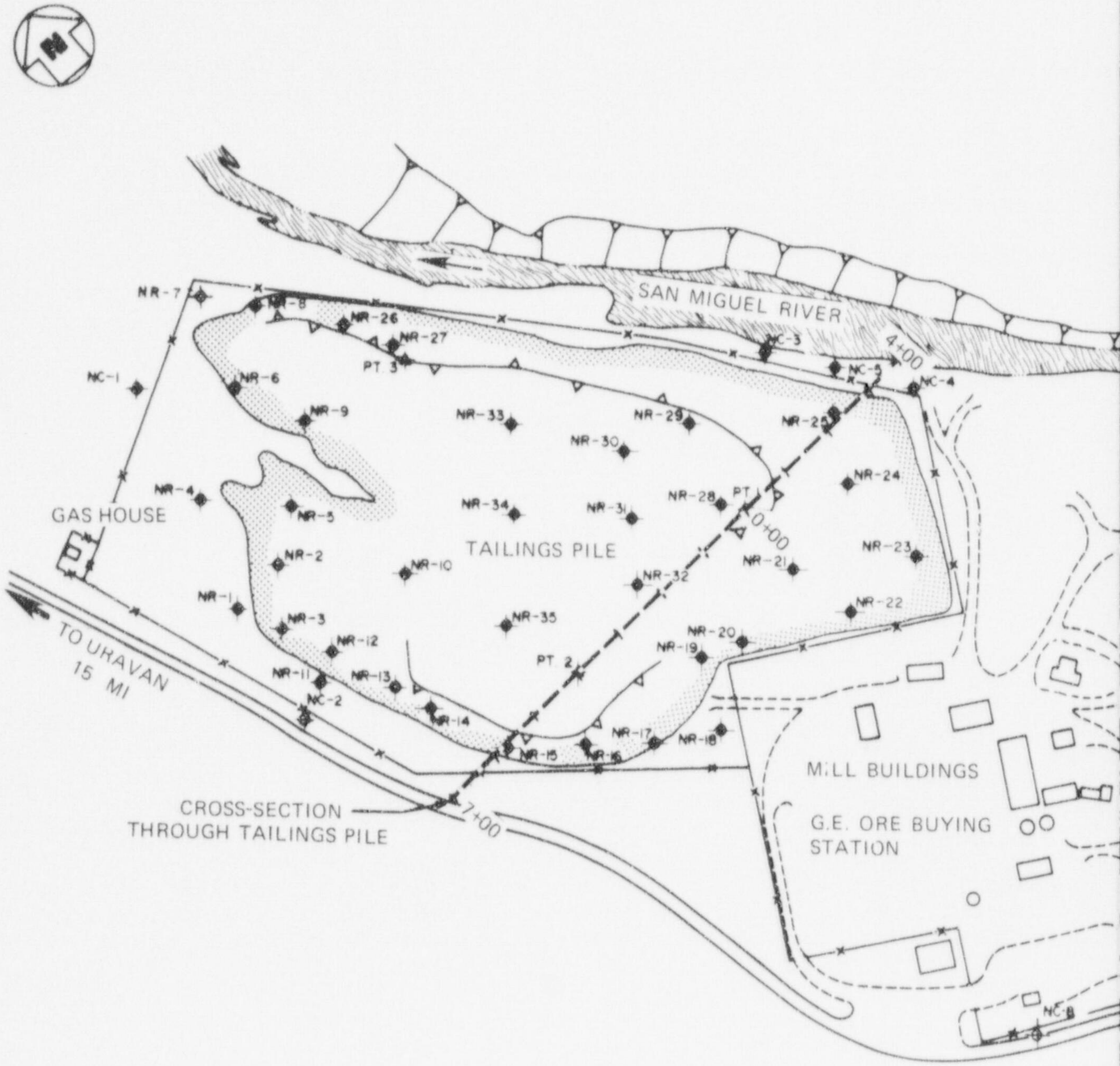
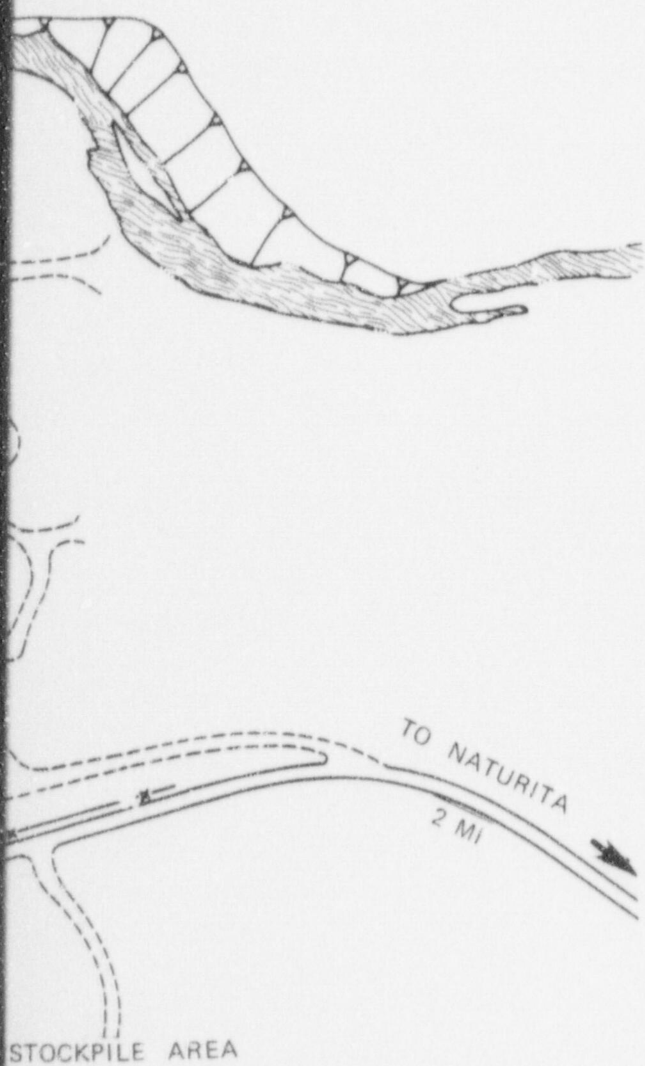


FIGURE 2-3. DESCRIPTIVE MAP



APERTURE CARD

Also Available on Aperture Card

NOTE:

MAP DEVELOPED FROM AERIAL PHOTOGRAPH

LEGEND

EDGE OF TAILINGS

HOLE LOCATION

SUDDEN CHANGE IN SLOPE (DOWNWARD)

0 100 200 300 400 500 FT

9810210025-02

130-07

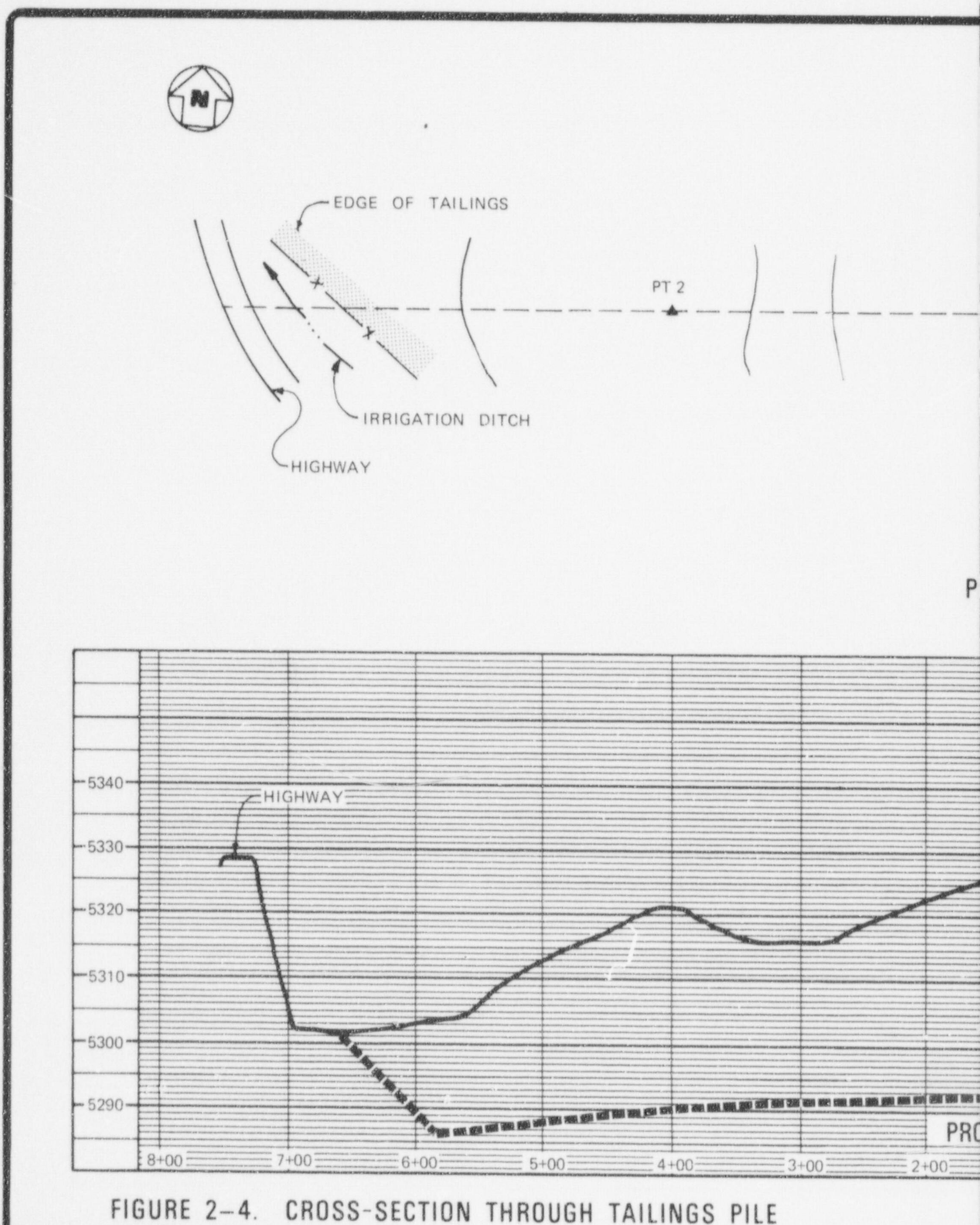
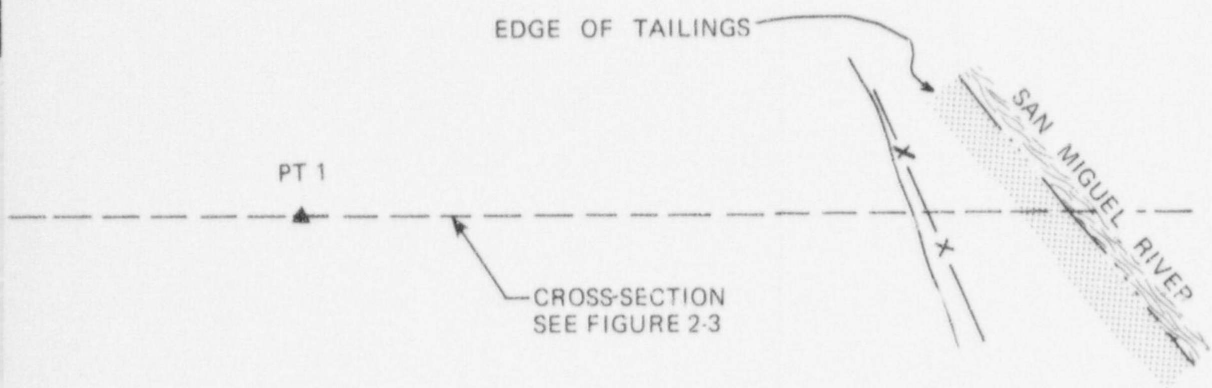


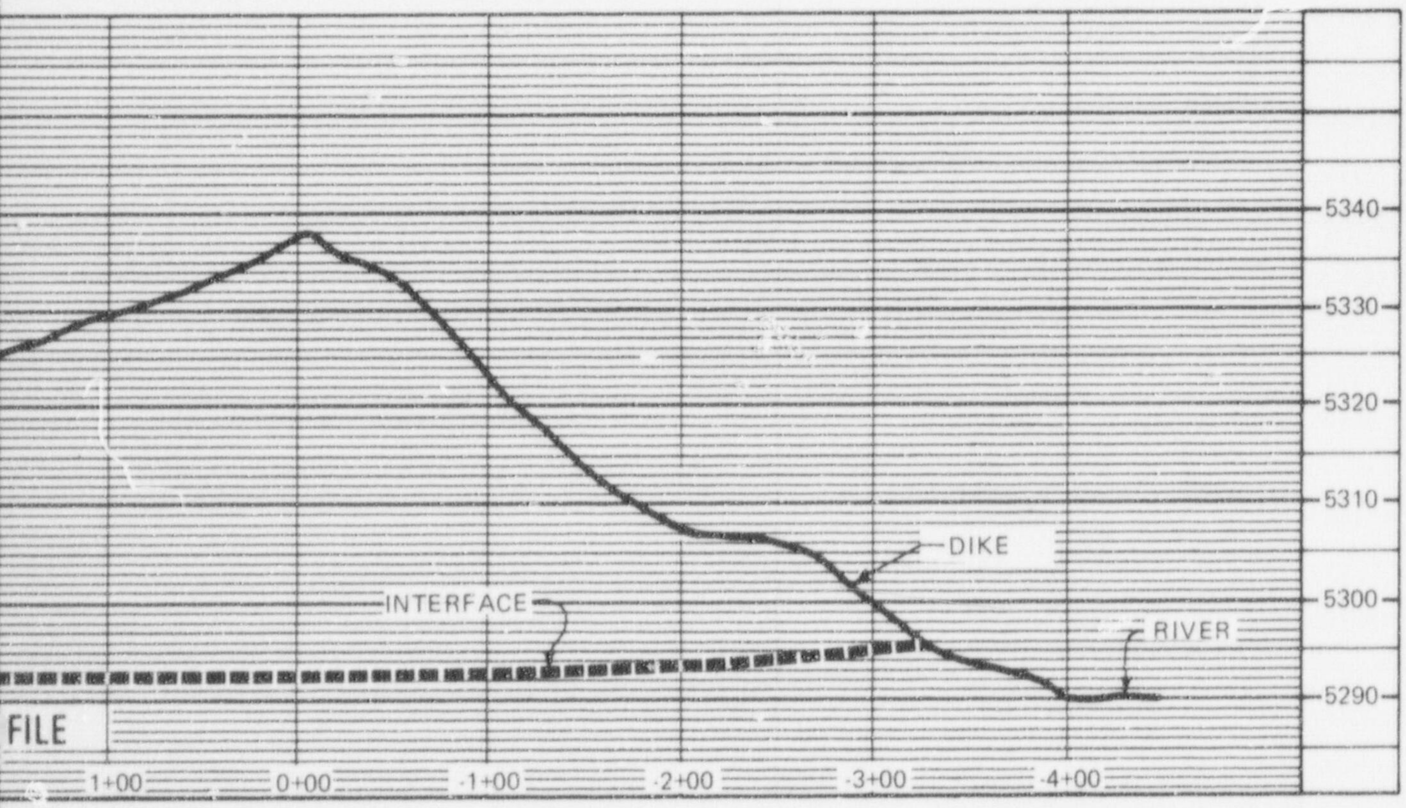
FIGURE 2–4. CROSS-SECTION THROUGH TAILINGS PILE



APERTURE CARD

Also Available on Aperture Card

LAN



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SYSTEM	FORMATION	THICKNESS (FT)	CHARACTER	POSITION OF THE TAILINGS
CRETACEOUS	MANCOS SHALE	2,000 - 5,000	GRAY SHALE; FORMS VALLEYS AND SLOPES; AQUICLUDE	
	DAKOTA SANDSTONE	0 - 200	GRAY AND BROWN SANDSTONE, SHALE AND CONGLOMERATE; CAPS MESAS AND FORMS CLIFFS; LOW QUALITY, LOW QUANTITY AQUIFER	
	BURRO CANYON FORMATION	50 - 250	BLUFF CONGLOMERATIC SANDSTONE AND MAROON AND GREEN MUDSTONES; FORMS SLOPES, SANDSTONES FORM CLIFFS, LOW QUALITY, LOW QUANTITY AQUIFER	
JURASSIC	MORRISON FORMATION	300 - 500	BRUSHY BASIN MEMBER: VARICOLORED SHALES, SOME SANDSTONE; FORMS SLOPES; SANDSTONES YIELD WATER	← NATURITA TAILINGS
			SALT WASH MEMBER: LIGHT COLORED SANDSTONE, RED MUDSTONE, OCCASIONAL LIMESTONE; FORMS BENCHES; SANDSTONES YIELD WATER	
	SUMMERVILLE FORMATION	0 - 400	VARICOLORED MUDSTONES, THIN SANDSTONE UNITS; FORMS SLOPES; AQUICLUDE	
	ENTRADA SANDSTONE	50 - 1,000	MOAB MEMBER: FINE GRAINED WHITE SANDSTONES; FORMS STEPS; AQUIFER	
			SLICK ROCK MEMBER: LIGHT COLORED MASSIVE SANDSTONE; FORMS CLIFFS; AQUIFER	
TRIASSIC(?)	KAYENTA FORMATION	0 - 200	LENTICULAR SANDSTONES AND RED/PURPLE MUDSTONES; FORMS BENCHES, SANDSTONE ARE POTENTIAL LOW QUANTITY AQUIFERS	
TRIASSIC	WINGATE SANDSTONE	200 - 400	LIGHT COLORED MASSIVE SANDSTONES; FORMS CLIFFS; LOW QUANTITY AQUIFER	
OLDER SEDIMENTARY ROCKS				

FIGURE 2-5. SIMPLIFIED STRATIGRAPHIC COLUMN

130-07

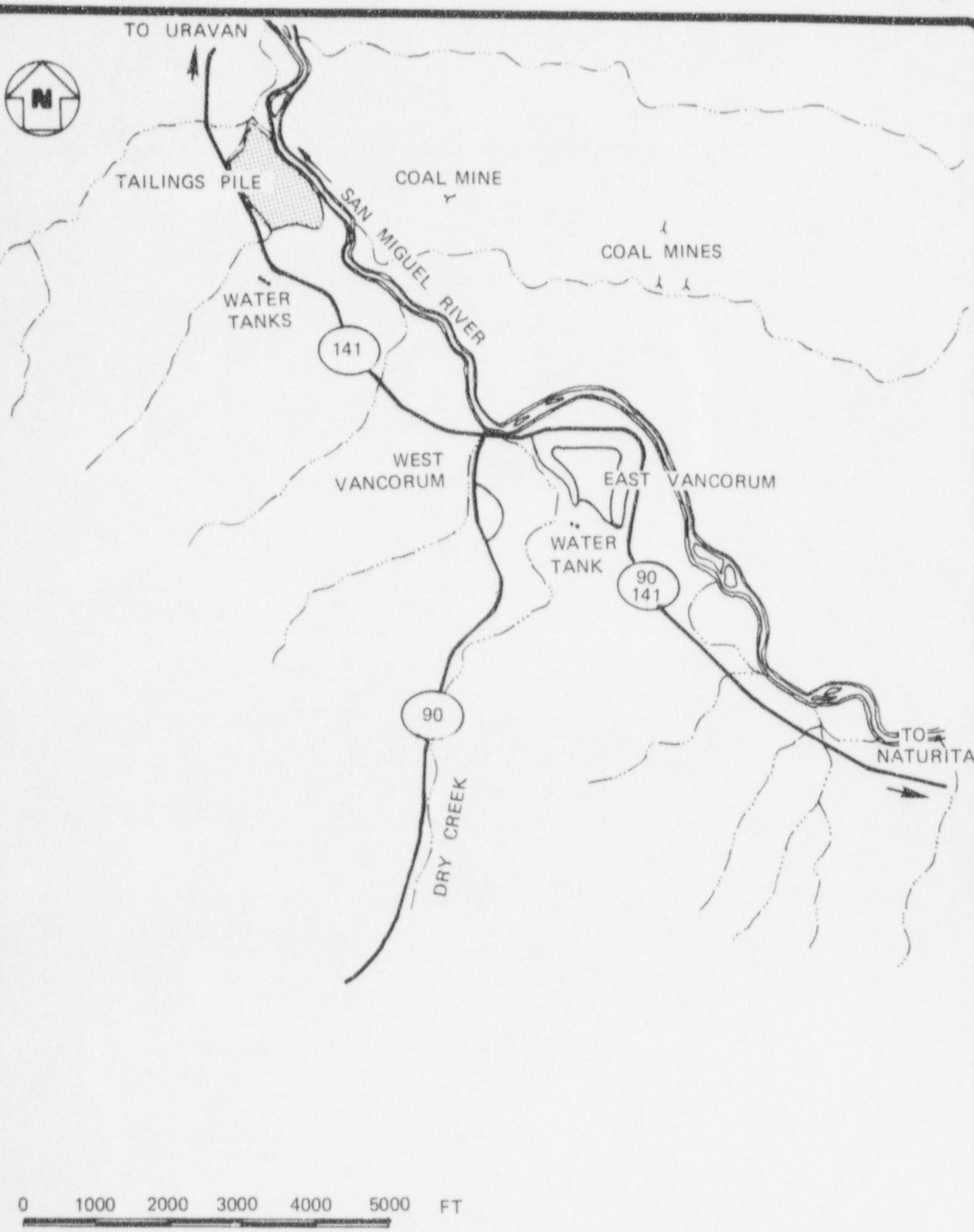
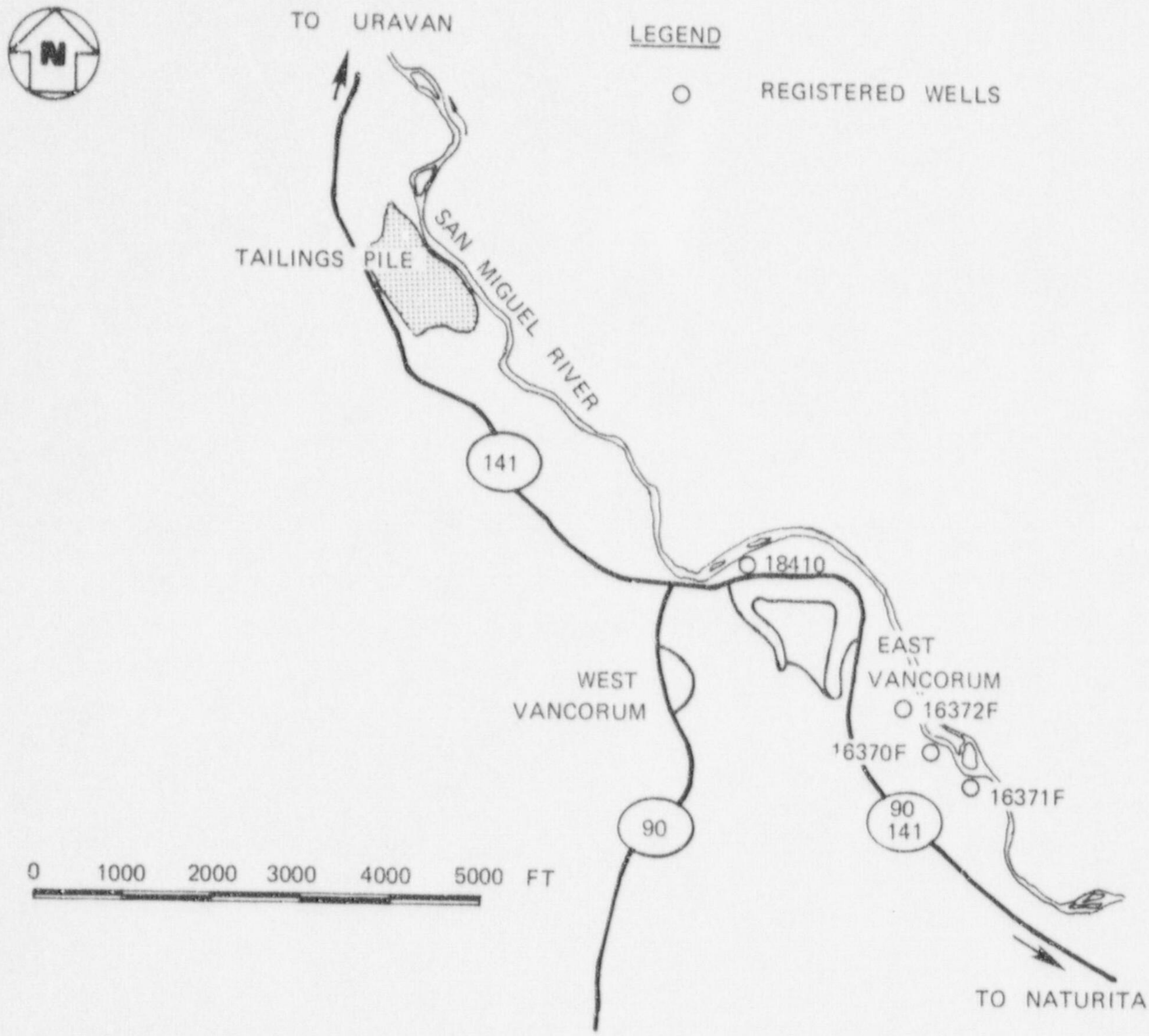


FIGURE 2-6. SURFACE DRAINAGE

130-07



Permit No.	Location	Yield (gal/min)	Depth (ft)	Static Water Level
18410	SW 1/4 SE 1/4, Sec. 14, T46N, R16W Non-Alluvial Well	8.0	240	218
16370F	SW 1/4 NW 1/4, Sec. 24, T46N, R16W	200	50	10
16371F	SW 1/4 NW 1/4, Sec. 24, T46N, R16W	200	50	10
16372F	SW 1/4 NW 1/4, Sec. 24, T46N, R16W	200	15	3

FIGURE 2-7. REGISTERED WELLS NEAR NATURITA

130-07

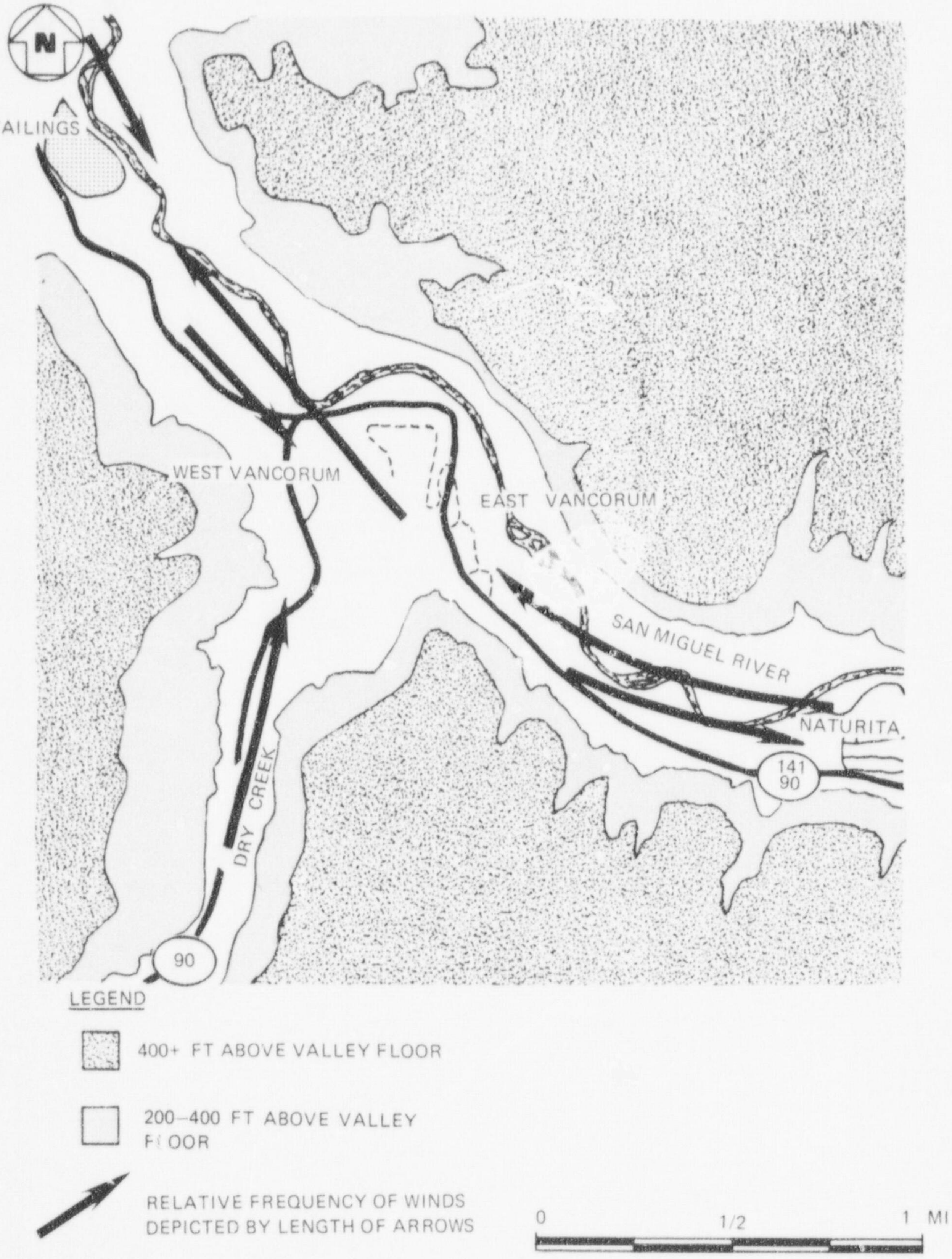


FIGURE 2–8. WIND MAP

130-07

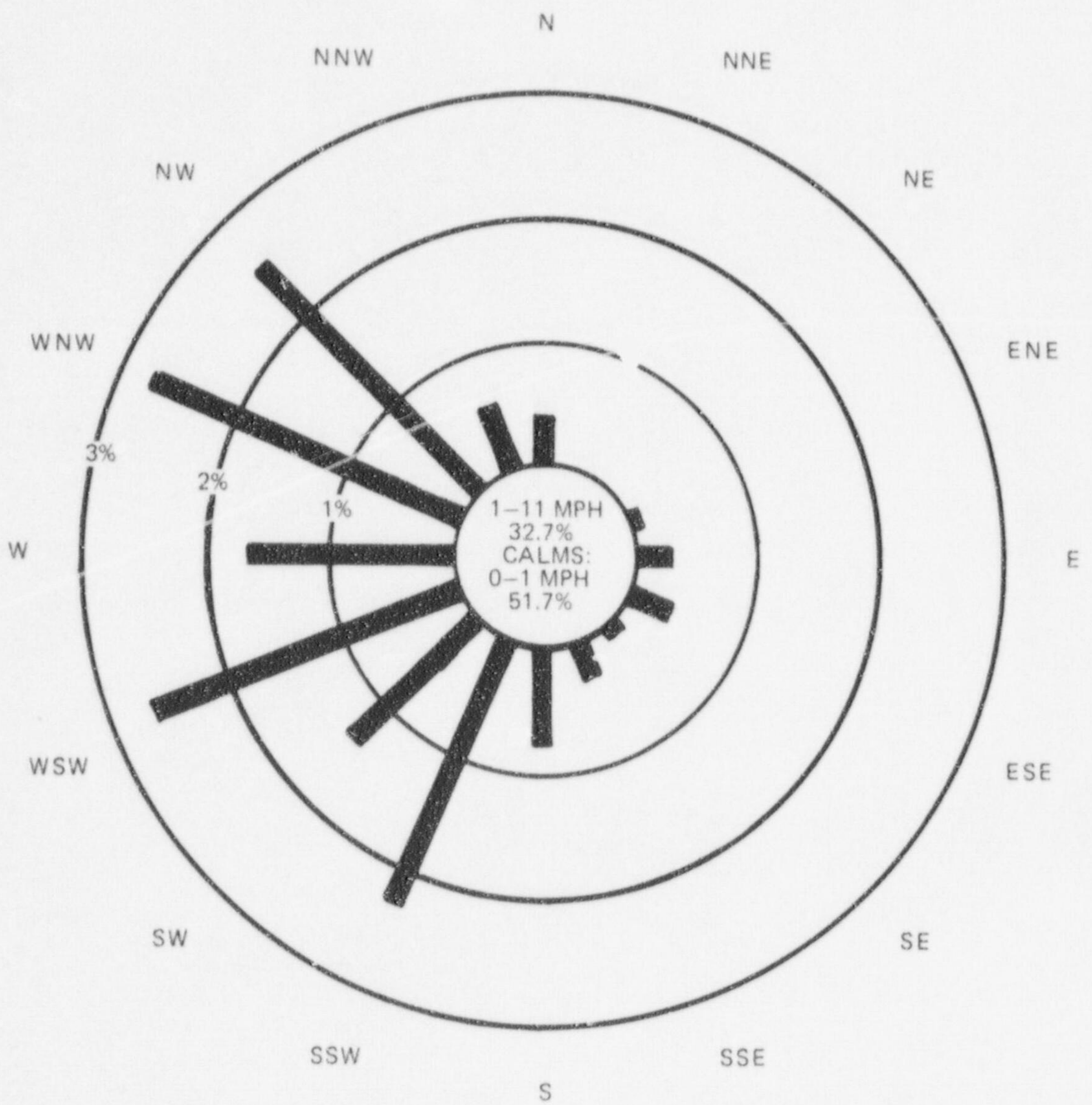


FIGURE 2-9. HOPKINS–MONTROSE COUNTY AIRPORT SURFACE WIND ROSE (CUMMULATIVE DATA FROM 1970 AND 1971)

130-07

TABLE 2-1

TAILINGS SITE MATERIALS

Material	Volume (Yd^3)	Weight (Tons)*
Tailings	521,000	704,000
Debris and Rubble	5,000	8,000
Stabilization Cover	16,000	22,000
Total	542,000	734,000

*Weight based on average existing densities which contain moisture

TABLE 2-2

PHYSICAL PROPERTIES AND pH OF THE TAILINGS

Sample Location[a]	Moisture (%)	Bulk Density (lb/ft^3)	pH (5% water by wt)
NC - 2 Comp 0.0 - 5.0 ft	0.70	111.0	6.70

[a]See Figure 2-3 for location

TABLE 2-3

ASSAY RESULTS OF COMPOSITE TAILINGS AND BACKGROUND SAMPLES

Percentage by Weight

Element	Atomic Absorption	Spectrographic	Chemical	AEC* Estimate	Background Composite
Aluminum	--	0.01-1.0	--	--	--
Arsenic	0.0059	--	--	--	0.0000636
Barium	0.0172	--		--	--
Boron	--	<0.01		--	--
Cadmium	0.0000071	--	--	--	--
Calcium	--	0.01-1.0	--	--	--
Chromium	0.000350	--	--	--	--
Cobalt	0.00092	--	--	--	--
Copper	0.0054	<0.01	--	--	--
Cyanide	<0.000001	--	--	--	--
Gallium	--	<0.01	--	--	--
Iron	1.640	>1.0	--	--	--
Lead	0.0048	<0.01	--	--	--
Magnesium	--	0.01-1.0	--	--	--
Manganese	--	<0.01	--	--	--
Mercury	<0.0000001	--	--	--	--
Molybdenum	--	--	--	--	--
Nickel	--	<0.01	--	--	--
Potassium	--	0.01-1.0	--	--	--
Selenium	0.000047	--	--	--	<0.0000001
Silicon	--	>1.0	--	--	--
Silver	0.00011	--	--	--	--
Sodium	--	0.01-1.0	--	--	--
Titanium	--	<0.01	--	--	--
Uranium (U_3O_8)	--	--	0.050	0.047	<0.0000001
Vanadium (V_2O_5)	--	0.01-1.0	0.289	--	0.000168
Zinc	0.0075	--	--	--	--

*Calculated tails assay based on plant operation[1]

CHAPTER 2 REFERENCES

1. Phase I "Report on Conditions of Uranium Millsite and Tailings at Naturita, Colorado"; AEC; Grand Junction, Colorado; Oct 1974.

2. R. C. Merritt; The Extractive Metallurgy of Uranium; Colorado School of Mines Research Institute; Golden, Colorado; 1971.

3. "Review of Uranium Mill Tailings Status"; Report No. 4; R. J. Gidney, Director Construction and Supply Division; GJO.

4. Corps of Engineers, U.S. Army; correspondence dated 23 Aug, 1974 from George C. Weddell, Chief Engineering Division, to Robert Kaufman; EPA.

5. "Meteorology Affecting Uranium Tailings at Naturita, Colorado"; unpublished report by URS Company; Denver, Colorado; 1976.

CHAPTER 3

RADIOACTIVITY AND POLLUTANT IMPACT ON THE ENVIRONMENT

CHAPTER 3

RADIOACTIVITY AND POLLUTANT IMPACT ON THE ENVIRONMENT

The principal objective of the assessment in this chapter is to determine the magnitude and characteristics of the radiation emitted from the Naturita uranium tailings pile and the resulting potential exposure to the population residing and working in the vicinity of Naturita, Colorado. In addition, this chapter describes briefly the potential radioactive and chemical pollutants and their pathways in the environment. The notations and abbreviations used are given in Table 3-1.

3.1 RADIOACTIVE MATERIAL CHARACTERISTICS

Many elements spontaneously emit subatomic particles; therefore, these elements are radioactive. For example, when the most abundant uranium isotope, ^{238}U undergoes radioactive decay, it emits a subatomic particle called an alpha particle; the ^{238}U after undergoing decay becomes ^{234}Th, which is also radioactive; and ^{234}Th subsequently emits a beta particle and becomes ^{234}Pa. As shown in Figure 3-1, this process continues with either alpha or beta particles being emitted, and the affected nucleus thereby evolves from one element into another. It is noted in Figure 3-1 that ^{230}Th decays to ^{226}Ra, which then decays to ^{222}Rn, an isotope of radon. Radon, a noble gas, does not react chemically. The final product in the chain is ^{206}Pb, a stable isotope that gradually accumulates in ores containing uranium. Uranium ore contains ^{226}Ra and the other daughter products of the uranium decay chain. One of the daughters of ^{226}Ra is the isotope ^{214}Bi, which emits a significant amount of electromagnetic radiation known as gamma radiation. Gamma rays are very similar to X-rays, only more penetrating. The ^{214}Bi is the principal contributor to the gamma radiation exposure in the uranium-radium decay chain.

Besides knowing the radioactive elements in the decay chain, it is also important to know the rate at which they decay. This decay rate, or activity, is expressed in curies (Ci) or picocuries (pCi), where 1 pCi equals 10^{-12} Ci or 3.7×10^{-2} disintegrations per second. The picocurie often is used as a unit of measure of the quantity of a radioactive element present in soil, air, and water.

Another important parameter used in characterizing radioactive decay is known as the "half life", $T_{1/2}$. This is the time that it takes for half of any initial quantity of the radioactive atoms to decay to a different isotope. For example, it takes 4.5×10^9 yr for half the ^{238}U atoms to decay to ^{234}Th. Similarly, half of a given number of ^{222}Rn atoms will decay in 3.8 days.

The activity and the total number of radioactive atoms of a particular type depend upon their creation rates as well as their half life for decay. If left undisturbed, the radioactive components of the decay chain shown in Figure 3-1 all reach the same level of activity, matching that of the longest-lived initiating isotope. This condition is known as secular equilibrium. When the uranium is removed in the milling process, ^{230}Th, which is not removed, becomes the controlling isotope. After processing the ore for uranium, the thorium, radium, and other members of the decay chain remain in the spent ore solids in the form of a waste slurry. The slurry is pumped to tailings ponds. The sands and slimes that remain constitute the tailings piles. Generally, as at Naturita, the slimes constitute only 20% of solid waste material, but they may contain 80% of the radioactive elements of major concern: radium, and its daughters.

3.2 RADIATION EFFECTS

The radioactive exposure encountered with uranium mill tailings occurs from the absorption within the body of the emitted alpha and beta particles, and gamma radiation. The range of alpha particles is very short; they mainly affect an individual when the alpha emitter is taken internally. Beta particles have a much lighter mass than alphas, and have a longer range; but they still cause damage mainly to the skin or internal tissues when taken internally. Gamma rays, however, are more penetrating than X-rays and can interact with all of the tissue of an individual near a gamma-emitting material.

The biological effects of radiation are related to the energy of the radiation; therefore, exposure to radiation is measured in terms of the energy deposited per unit mass of a given material. In the case of radon and its daughter products, the principal effect is from alpha particles emitted after the radon and its daughter products are inhaled.

The basic units of measurement for the alpha particles from short-lived radon daughters are the working level (WL) and the working level month (WLM). The working level is defined as any combination of the short-lived radon daughters in a liter of air that will result in the ultimate emission of 1.3×10^5 MeV of alpha energy. The working level is so defined because it is a single unit of measure, taking into account the relative concentrations of radon daughter products which vary according to factors such as ventilation. One WLM results from exposure to air containing a radon daughter concentration (RDC) of 1 WL for a duration of 170 hr.

The basic units of measurement for gamma radiation exposure and absorption are the roentgen (R) and the rad. One R is equal to an energy deposition of 88 ergs/g of dry air, and 1 rad is the dose that corresponds to the absorption of 100 ergs/g of material. The numerical difference between the magnitude of the two units is often less than the uncertainty of the measurements, so that exposure of 1 R is often assumed equivalent to an absorbed dose of 1 rad or a gamma dose of 1 rem.

3.3 NATURAL BACKGROUND RADIATION

There are several sources of radiation that occur naturally in the environment. Natural soils contain trace amounts of uranium, thorium, and radium that give rise to radon gas and to alpha, beta, and gamma radiation. The average background value in 18 off-site soil samples for each member of the uranium decay chain, assuming equilibrium, was 1.5 pCi/g.(1) The sample locations taken within a 130-mi radius of Naturita and the corresponding ^{226}Ra concentrations are shown in Figure 3-2. No previous measurements are available for the area. Another natural source of radiation in the environment arises from the decay of ^{232}Th, the predominant thorium isotope. The half-life of ^{232}Th is 1.4×10^{10} yr. It is also the parent of a decay chain containing isotopes of radium and radon. The average background value in the same off-site samples for each member of the thorium decay chain, assuming equilibrium, is about 1.1 pCi/g of soil. Table 3-2 lists the major background radioactive sources. It is noted that background values of the radium and thorium chains vary with locations by factors of 6 and 14, respectively.

Background values of radon concentrations were measured at five locations using continuous radon monitors supplied by ERDA(2) and are shown in Figure 3-3. An average background value of 2.0 pCi/l was obtained from the 24-hr samples in the vicinity of the Naturita tailings pile. However, the range of the measurements extends from 1.0 to 3.2 pCi/l.

Background gamma ray levels, as measured 3 ft above the ground, also were determined at several locations within 1 mi from the site by using a calibrated and energy compensated Geiger Mueller detector. A value of 10 μR/hr was established as the average background level, but the values ranged from 7 to 13 μR/hr.(1) Cosmic rays are part of the radiation levels. The contribution from cosmic rays is generally dependent upon the altitude and is approximately 7 μR/hr in the Naturita area,(3) or approximately 70% of the measured average background value.

3.4 RADIATION EXPOSURE PATHWAYS AND CONTAMINATION MECHANISMS

As noted previously, the principal environmental radiological implications and associated health effects of uranium mill tailings are related to radionuclides of the ^{238}U decay chain: primarily ^{230}Th, ^{226}Ra, ^{222}Rn, and ^{222}Rn daughters. Although these radionuclides occur in nature, their concentrations in tailings material are several orders of magnitude greater than in average natural soils and rocks. The major potential routes of exposure to man are:

(a) Inhalation of the ^{222}Rn daughters, from decay of

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(1) See end of chapter for references.

^{222}Rn escaping from the pile; the principal exposure hazard is to the lungs.

(a) External whole-body gamma exposure directly from the radionuclides in the tailings pile (primarily from ^{214}Bi) and in surface contamination from tailings spread in the general vicinity of the pile.

(c) Inhalation of windblown tailings; the primary hazard relates to the alpha emitters ^{230}Th and ^{226}Ra, each of which causes exposure to the bones and the lungs.

(d) Ingestion by man of ground or surface water contaminated from either radioactivity (primarily from ^{226}Ra) leached from the tailings pile or from solids physically transported into surface water.

(e) Erosion and removal of tailings material from the pile by flood waters or heavy rainfall; this can create additional contaminated locations with the same problems as the original tailings pile.

(f) Physical removal from the tailings pile also provides a mechanism for contamination of other locations.

(g) Contamination of food through uptake and concentration of radioactive elements by plants and animals is another pathway which can occur; however, this pathway was not considered in this assessment.

The extent of radiation and pollution transport from the tailings into the environment is discussed in the following paragraphs.

3.4.1 Radon Gas Diffusion and Transport

Field measurements of the radon exhalation flux from the tailings using the charcoal canister technique[4] are listed in Table 3-3. The current values range from 763 to 2540 pCi/m^2-s on the tailings pile. The canisters were placed on the pile for 4 hr on May 10, 2 days after a rainfall. The soil on the surface was dry, but the cover material was slightly moist below the surface. In general, reported values of radon flux vary considerably from time to time at a single sampling location due in part to differing moisture, soil, and climatological factors, to major changes in pile configuration between different locations, and to the difficulty of performing such measurements.

Radon gas above background, considered to be from the pile, has been detected at a distance of 0.4 mi from the site. Measurement locations and corresponding 24-hr average randon concentrations are illustrated in Figure 3-3. The average background radon concentration was 2.0 pCi/l and the radon concentration measured above the pile was 252 pCi/l. In general, the radon concentrations measured downstream from the pile near the river were higher than expected from the pile. These elevated readings could be due to radioactive materials in and near the riverbed.

Variations in radon concentration at two locations during the measurement period and the existing weather conditions are shown in Figures 3-4 and 3-5. The sample location for Figure 3-4 is at a bridge 0.9 mi north-northwest of the tailings pile. Figure 3-5 illustrates the measurements 3 mi northwest of the tailings site. A diurnal variation of ^{222}Rn concentration is evident in both figures, indicating the presence of a source of ^{222}Rn greater than background near the measurement locations. Thus, the higher-than-normal background values are not merely the result of a high instrument background count. The location of the tailings pile in the San Miguel Canyon resulted in channeling of the radon and higher radon concentrations at the sampling locations in the canyon. These 24-hr measurements were obtained during atmospheric conditions normal for that time of year (May). Data were not recorded during wind or rainstorms.

Radon concentration measurements taken during this program generally indicated increased concentrations during the night, with reduced values during the day. The increase in concentration is probably the result of an inversion condition and reduced wind velocities. High winds tend to disperse the radon and generally do not result in significantly higher measurements of radon concentration downwind from the tailings piles.

The radon concentration measurements are plotted in Figure 3-6 as a function of distance from the edge of the tailings pile. Also shown in the figure are the FB&DU model results. Model calculations were performed with annual meteorology data to provide an additional estimate of the radon concentration in the vicinity of the pile. The FB&DU model first determines radon flux and the total radon releases from the pile with diffusion theory using radium soil concentrations, and pile configurations deduced from the drilling and survey data. Then, the radon transport off-pile is calculated by Gaussian diffusion(6) plus wind drift conditions. Meteorology data were obtained for the San Miguel Canyon from a portable weather station during the period of the test as well as annual data from the Nucla Airport for 1971 and 1972. Since the Naturita pile is in a well-defined valley, and the airport is on a plateau above the town, the surface wind direction frequencies at the airport are not representative of the pile. The surface wind direction frequencies were modified to reflect higher directional probabilities up and down the canyon, as is the case due to diurnal wind direction characteristics. This modification resulted in a conservative meteorology prediction for Figure 3-6.

From the maximum model result, a best estimate curve of radon concentration-versus-distance was formulated for the Naturita tailings pile. Radon concentration data collected in the vicinity of the tailings pile are due to other sources (e.g. mines, ore stockpile) as well as the tailings. Consequently, the radon concentration measurements are above those predicted by the model for the tailings pile alone. This best estimate curve is shown in Figure 3-6. This curve was used to calculate potential health effects resulting from radon diffusing from the Naturita tailings.

3.4.2 Direct Gamma Radiation

The external gamma radiation (EGR) levels measured on the tailings pile and stockpile areas are shown in Figure 3-7. These measurements include background and were taken with calibrated, energy compensated Geiger Mueller detectors.(1) The highest-gamma radiation rate (780 μR/hr) was measured on the western edge of the tailings pile. Gamma measurements on the pile ranged from 66 to 780 μR/hr. In the former stockpile area across Colorado Highway 141, gamma radiation ranged from three times background (36 μR/hr) to 380 μR/hr.

Gamma rate measurements away from the tailings pile, taken at 100-yd intervals, reached background levels at less than 0.2 mi to the northeast and southwest of the site. Along the San Miguel River Valley, where the wind has carried tailings, background levels of gamma radiation were reached at a distance of 0.3 mi in the southeasterly direction. In the north-northwesterly direction the gamma radiation was still two times background at 0.8 mi; however, the gamma radiation in this direction beyond 0.3 mi is mainly caused by sources other than the tailings pile (e.g. natural surface deposits, spilled ore, tailings and mill stack contamination). These gamma radiation rate measurements are shown in Figure 3-8. The reduction of gamma radiation as a function of distance from the pile is shown in Figure 3-9.

3.4.3 Windblown Contaminants

Another pathway is the result of windblown tailings. Prevailing winds follow the river valley and are therefore from the northwest and southeast.

Figure 3-10 shows iso-exposure lines due to residual windblown tailings as determined by EPA.(6) If scattered tailings and ore are removed from inside the 40 μR/hr line (toward the pile), and if the pile is removed or covered to provide essentially complete gamma shielding, then the remaining tailings outside the line (away from the pile) would produce a new gamma exposure rate, 3 ft above ground, approximately equal to 40 μR/hr.

Surface and subsurface soil samples were taken in the area surrounding the tailings.(1) The sample locations and ^{226}Ra concentrations are shown in Figure 3-11. The data show levels of surface contamination to the southeast and higher levels to the north-northwest of the tailings pile. This scattering of tailings was also shown in the EPA study, in which the background level contour was not closed in the northern or southeastern directions. A soil sample taken 800 yd north of the site contains 60 times the average background concentration of ^{226}Ra. Another sample taken 1600 yd north-northwest of the pile contained 20 times the average background level of ^{226}Ra activity. While these surface samples were taken in the vicinity of the tailings pile, they did not appear to be windblown tailings. The high concentrations were probably due to spilled ore along the highway or to mill stack contamination.

No air particulate measurements were performed at the Naturita site.

3.4.4 Ground and Surface Water Contamination

Three water samples were taken from the San Miguel River in the vicinity of the Naturita tailings pile. A sample of unconfined ground water was taken from a drill hole and two samples were taken from standing water which had run off the tailings pile following a rainstorm. The ^{226}Ra concentration in these samples is shown in Figure 3-11.[1] An auger hole was drilled between the tailings pile and the river near the southeastern corner of the tailings pile. From this hole, unconfined ground water contained 0.22 pCi/l. The river sample taken upstream from the tailings contained 0.45 pCi/l, about one-fourth the ^{226}Ra contained in the sample taken immediately downstream from the tailings (1.70 pCi/l). Another sample, which contained 0.40 pCi/l, was taken 1 mi downstream from the tailings pile. The two samples of surface water obtained from water running off the tailings pile contained 4.4 and 8.6 pCi/l. From these data it appears that the tailings do cause some local contamination of the San Miguel River; however, the level of contamination is considerably below the EPA Drinking Water Regulations and does not appear to be a major ^{226}Ra radiological health hazard. The quality of the San Miguel River with respect to ^{226}Ra was monitored from 1961-1970. Average ^{226}Ra level during this period upstream from the tailings was 0.06 pCi/l and the average downstream was 0.17 pCi/l.[7]

3.4.5 Soil Contamination

The amount of ^{226}Ra activity in the tailings and the extent of leaching of radium from the tailings into the soil were determined by drilling auger holes around the edges of the tailings and into the soil beneath them. The radioactivity profile was measured in these holes with a Geiger tube probe with a lead shield that collimates the radiation. Soil samples also were taken from selected holes for radiometric analysis. The locations of the auger holes (labeled NC) are shown in Figure 2-3, Chapter 2.

Concurrently with the field work of this study, Ranchers Exploration and Development Company completed extensive soil boring of the pile for their own evaluation. These holes were also logged as part of the present work, but in most cases gamma measurements at the bottom of the holes did not reach background values. The locations of these holes (labeled NR) are shown in Figure 2-3, Chapter 2.

Typical ^{226}Ra activity profiles in the Naturita tailings and subsoil are shown in Figures 3-12 and 3-13. Figure 3-12 illustrates the ^{226}Ra profile at hole NC-2, located west of the tailings pile outside of the fence where eroded tailings cover the surface to a depth of about 4 ft. Sample analysis of the subsoil indicates radioactive contamination amounting to two times the average background value at 5 ft below the original surface.(1) Three auger holes were drilled along the riverbank of the San Miguel River, adjacent to the east fenceline of the tailings pile. Figure 3-13 illustrates the radiometric profile of one of these auger holes, NC-4. Although tailings were not identifiable in the muddy material, the activity levels are very high for surface contamination. The ^{226}Ra concentration reached twice the average background level about 8 ft below the surface. At hole NC-3, a 4-in.-thick layer of tailings was found 1 ft beneath the surface and ^{226}Ra concentration was four times the average background level 3 ft below the surface. These tailings are the remnant of the tailings washed off the pile during heavy rainstorms mentioned in Chapter 2. Slight contamination to 3 ft below the surface was measured in hole NC-1 outside the northwest fenceline. The range of contamination is from 3 to 6 ft beneath the tailings subsoil interface.

3.4.6 Off-Site Tailings Use

Some of the uranium tailings have been moved physically from the site and used as fill material under and around structures in Naturita and Nucla. These locations have been identified by a mobile survey and by follow-up gamma surveys of individual locations in 1976. The locations and survey results are discussed in Chapter 7 where remedial action is considered. The locations at which tailings are on vacant lands or are greater than 10 ft from structures were not subject to the criteria used in Phase II, but could constitute a problem in the future.

3.5 REMEDIAL ACTION CRITERIA

Radiological criteria established for this engineering assessment for possible remedial action applicable to uranium mill tailings are divided into two general categories: criteria applicable to structures with tailings underneath them or within 10 ft,(8) and criteria pertaining to the mill tailings site and open land.(9) Copies of the complete documents establishing these criteria are presented in Appendix A. Also given in Appendix A are the Grand Junction Remedial Action Criteria for Structures (10CFR712).

The criteria which apply to the structures are the guidelines published by the Surgeon General of the United States.(8) These guidelines recommend the following graded levels for remedial action in terms of the EGR levels and indoor RDC levels above background found within the dwellings constructed on or near uranium mill tailings:

EGR, mR/hr	RDC*, WL	Recommendation
Greater than 0.1	Greater than 0.05	Remedial action indicated
From 0.05 to 0.1	From 0.01 to 0.05	Remedial action may be suggested
Less than 0.05	Less than 0.01	No remedial action indicated

*Based upon yearly average values from six air samples of at least 100-hr duration taken at a minimum of 4-wk intervals throughout the year.

The radiological criteria for decontamination of inactive uranium millsites and for open areas are based upon EGR readings above background, measured 3 ft above ground. Decontamination should result in residual exposures that are as low as practicable. For this assessment the following criteria were used:

(a) For the tailings pile:

(1) Tailings should be covered so that residual gamma ray levels do not exceed 0.040 mR/hr above background. The area also should be designated a control area with restricted access.

(2) Where the site is not considered suitable for long-term stabilization, remove so that residual radium concentration in the soil does not exceed twice background values.

(b) Windblown tailings in open land areas near to or adjacent to the site:

(1) If gamma levels are less than 0.010 mR/hr above background, the land may be released for unrestricted use.

(2) If gamma levels exceed 0.010 mR/hr above background, cleanup should reduce the radium soil concentration to no more than twice background.

(3) If tailings removal is not practicable, residual

gamma levels should in any part of the area not exceed 0.040 mR/hr above background.

3.6 POTENTIAL HEALTH IMPACT

An assessment has been made of the potential health impact of the tailings pile. The six environmental pathways described in paragraph 3.4 were evaluated. A summary of the evaluation of each pathway is presented below:

(a) Radon Diffusion - inhalation of radon daughters from radon diffusion constitutes the most significant pathway and results in the largest estimated population dose.[1,10] Elevated concentrations were measured to 0.4 mi from the tailings pile.

(b) External Gamma Radiation - gamma radiation above background is measurable to distances up to 0.2 mi to the northeast and southwest of the pile, an area with very few inhabitants. People on site will receive some gamma exposure until the pile is covered with sufficient material to reduce the gamma radiation. Exposure to the local population within 0.3 mi from the pile has been evaluated and found to have negligible health impact compared with exposure from radon daughters.

(c) Airborne Activity - the limited, directional spread of significant quantities of windblown tailings toward inhabited areas indicates that direct inhalation or ingestion of tailings particles may be a minor component of the total population dose. This is a general result also reported at other uranium tailings piles.[11,12] Added stabilization of the Naturita tailings against wind erosion would eliminate the gradual accumulation of tailings off the site, particularly to the north and southeast if the tailings were not moved.

(d) Water Contamination - the low ^{226}Ra activity in nearby off-site surface water indicates slight ^{226}Ra contamination from the tailings, as confirmed by measurements since 1961.

(e) Subsoil Contamination - leaching of radioactive materials into the ground beneath the pile and at the millsite is considerable in some areas. Water analyses do not indicate significant contamination from this pathway, however.

(f) Physical Removal - tailings which have been placed near a structure or used in its construction are sources for elevated gamma levels and radon daughter concentrations in the structure. Radiation exposure to individuals living or working in these structures can be significant. (For details refer to Chapter 7.)

Only the potential health effects from the inhalation of radon daughters (pathway a) are estimated quantitatively in this assessment because this pathway constitutes the most significant pathway.[10,12] Furthermore, it is assumed that the uncertainty in the estimates of the potential health effects from this pathway far exceeds the magnitude of the health effects from the other pathways.

It is extremely difficult to predict with any assurance that a specific health effect will be observed within a given time after chronic exposure to low doses of toxic material. Therefore, the usual approach to evaluation of the health impact of low-level radiation exposures is to make projections from observed effects of high exposures on the basis that the effects are linear, using the conservative assumption of no threshold for the effects. The resulting risk estimators also have associated uncertainties due to biological variability among individuals and to unknown contributions from other biological insults which may be present simultaneously with the insult of interest. No synergistic effects are considered explicitly in this analysis. For the purpose of this engineering study, lung cancer is the potential health effect considered for RDC. The health effects were estimated using both an absolute and a relative risk model.

3.6.1 Assumptions and Uncertainties in Estimating Health Effects

Since radiation exposure from ^{222}Rn daughters is expressed in terms of working levels (WL) and working level months (WLM), total population exposures as well as health risk estimates are based upon these units, i.e. person-WLM. Exposures and resulting health effects often are expressed in terms of rems; however, estimates of the WLM-to-rem conversion factor for internal lung exposure to alpha particles from ^{222}Rn daughters vary by over an order of magnitude. Presently, there are significant differences of opinion related to the choice of an appropriate conversion factor. Consequently, disagreements of calculated health effects from RDC occur when these effects are based on the rem.

The absolute risk estimator used in this assessment is that given in the report of the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR report).[13] This report presents risk estimators for lung cancer derived from epidemiological studies conducted on two groups of miners, namely:

> 3 cancers per year per 10^6 person-WLM exposure for uranium miners
>
> 8 cancers per year per 10^6 person-WLM exposure for fluorspar miners

Therefore, the average of these two values was chosen as the risk estimator for use in this study. This estimator then is:

6 cancers per year per 10^6 person-WLM exposure

A dose from a given ingestion or inhalation of radionuclides varies widely due to differences in age (infants-adults), physical size, etc. This and other components of natural biological variability which exist among members of any given population, as well as the differences between exposure conditions in residences and mines, give rise to an uncertainty on the order of a factor of 3 in this parameter.[14]

The commitment, then, of 6 cancers per year has a statistical basis and relates to a total population exposure of 10^6 person-WLM. If a cancer does occur it likely will be evident during the 30-yr period following the initial exposure and latency period.[15] When the exposure is continual over an individual's lifetime, this commitment is cumulative and the risk per year increases to an ultimate value of 6 times 30, or:

180 effects per year for 30 x 10^6 person-WLM
total cumulative exposure

This mathematical expression also can be interpreted in terms of the average annual risk to an individual per unit of exposure. For example, an individual with a continuous exposure of 1 WLM annually has about a 2 x 10^{-4} probability each year of developing lung cancer from this exposure. Several investigations have been reported recently concerning the association between lung cancer incidence and RDC exposures in miners.[14,16,17] These investigations yielded risk estimator values consistent with the risk estimator used in the present assessment. The relative risk estimator can give a value several factors larger than the absolute risk estimator.[18]

For the purposes of this assessment, equivalent working levels inside structures are determined from the radon concentration assuming a 50% equilibrium condition. This yields the following conversion factor:

1 pCi/l of ^{222}Rn = 0.005 WL

It is assumed that the component of indoor radon concentration due to radon exhaled from the piles is equal to the corresponding outdoor concentration component at that point. However, the concentration of radon daughters is higher indoors owing to reduced ventilation and to other sources of radon, such as building materials.

The exposure rate in terms of WLM/yr can be obtained from a continuous 0.005 WL concentration (equivalent to 1 pCi/l ^{222}Rn concentration) as follows:

$$(0.005 \text{ WL}) \left(8766 \frac{\text{hr}}{\text{yr}}\right) \left[\frac{1 \text{ WLM}}{1 \text{ WL } (170 \text{ hr})}\right] = 0.25 \frac{\text{WLM}}{\text{yr}}$$

The risk estimator[13] used for continual exposure to gamma radiation is:

> 100 effects per year for 10^6 person-rem continuous exposure to gamma radiation

In this assessment it is assumed that a gamma exposure of 1 R in air is equivalent to a dose of 1 rem in soft tissue.

3.6.2 Health Effects

The best-estimate curve of radon concentration-versus-distance (Figure 3-6) is used to determine the health effects due to radon from the Naturita pile. First, an indoor radon daughter concentration is deduced from the outdoor radon concentration curve using the conversion factor 1 pCi/l of ^{222}Rn outside equals 0.25 (WLM/yr) inside, then, the resulting RDC distribution is multiplied by the risk estimators given previously to yield the health effect risk per person as a function of distance from the pile. The estimated annual radiation-induced lung cancer risk due to the pile is given in Figure 3-14 as a function of distance from the edge of the pile for prolonged continuous exposure. The curve shown in the figure represents the estimated annual radiation-induced risk from the Naturita tailings pile plus the average lung cancer risk per year from all causes for residents of the State of Colorado.[19]

Health effects from total population RDC exposures for the area within 4 mi from the perimeter of the tailings pile are obtained by multiplying the health effect risk per person from the curve given in Figure 3-14 by the population distribution as a function of distance from the pile. The results are given in Table 3-4. Annual lung cancer events are calculated using estimated population data for 1973. There were at that time 1,900 persons living within 4 mi of the perimeter of the tailings pile, and it has been assumed that no growth has occurred since that time.

Health effects were determined for both a yearly and cumulative basis. Three population predictions were used: static, 2%, and 4%. The 2% and 4% rates were decreased linearly such that zero growth was attained after 25 yr.

The health effect values are obtained by converting the appropriate radon concentrations in the area within 4 mi of the tailings pile to an equivalent WLM/yr and multiplying it by 180 effects per year per 10^6 person-WLM and by the population. If the relative risk estimator is used, the health effects estimates are correspondingly larger than the ones given in Table 3-4. The uncertainty in the health effects estimation is about a factor of 4.

The 25-yr cumulative health effect values shown are quite low, even for the 4% population growth. The highest cumulative health effect value is 0.14 effects in 25 yr for the 4% population growth case. The health effects calculated are due only to pile radon. There are numerous other sources of radon in the area, as evidenced by the relatively high background values. There is substantial mining activity which indicates the presence of ore. In view of the high background health effect values, the Naturita tailings pile is not a significant health hazard. The predicted pile health effects are only about 2% of those due to background radon.

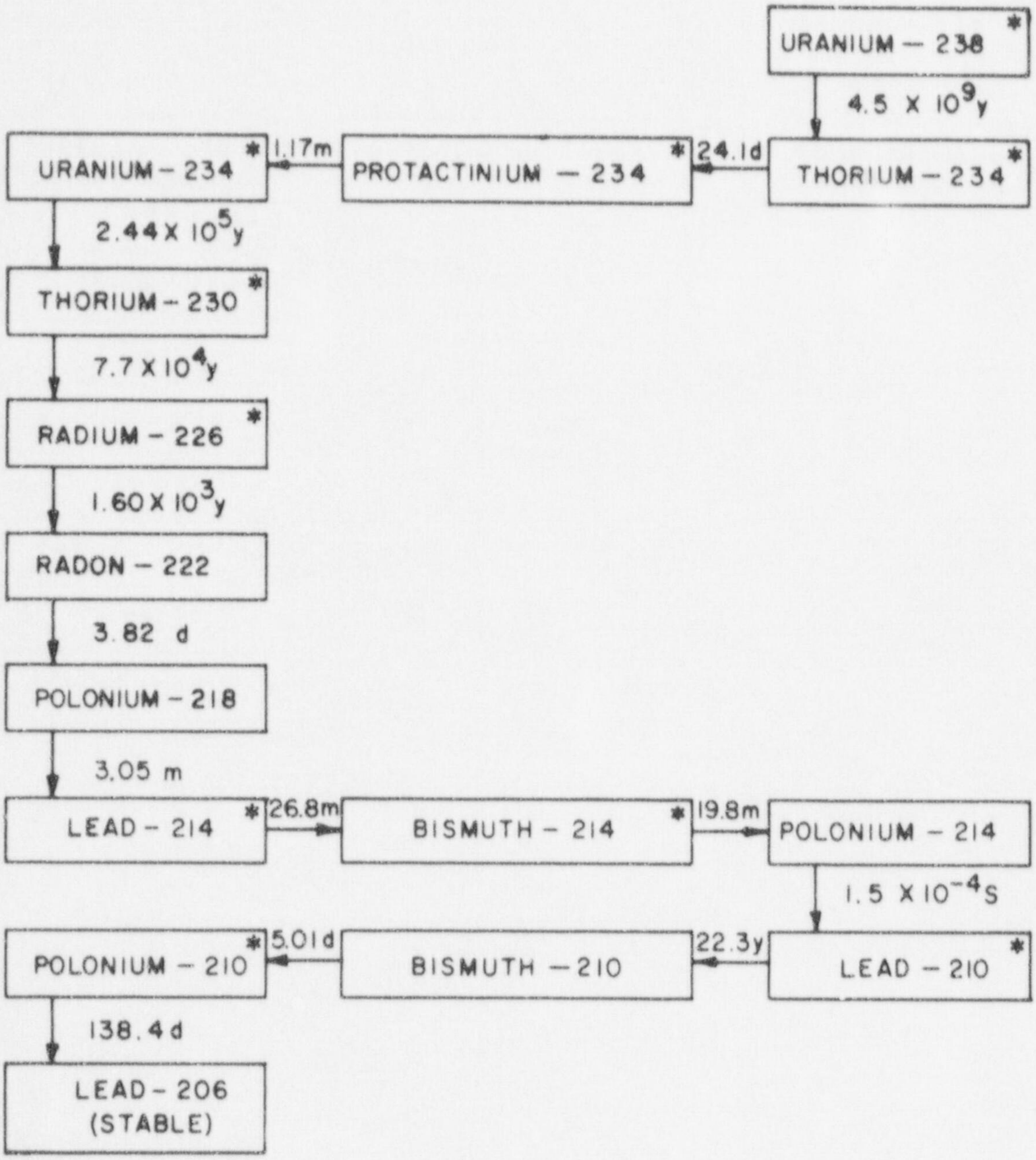
3.7 NONRADIOACTIVE POLLUTANTS

The tailings pile contains other potentially toxic materials. Chemical analyses of tailings samples from auger holes in the Naturita tailings pile showed arsenic and lead in concentrations between 40 and 60 ppm. Selenium and chromium concentrations measured 0.5 ppm and 3.5 ppm, respectively. Vanadium was present in concentrations as high as 3,000 ppm.

Four water samples were taken from the Naturita tailings pile and vicinity and chemically analyzed. The locations of these samples are shown in Figure 3-11. Samples A and C were obtained from the San Miguel River 100 yd upstream and 100 yd downstream from the pile, respectively. Samples B and D were taken from standing water in a ditch along the northern edges of the tailings pile.

All of these water samples, except sample A from the San Miguel River, contained selenium above the EPA Interim Drinking Water Regulations, as seen in Table 3-5. The selenium content increased about 30% in the San Miguel River as it flowed by the Naturita tailings pile to about 1.2 times the EPA standard of 0.01 mg/l. River samples both up and downstream from the tailings contained chromium at or above the EPA standard for drinking water. Standing water which had flowed off the tailings did not contain measurable amounts of chromium.

Standing water north of the tailings pile contained higher than acceptable levels of arsenic, lead, and selenium; however, the San Miguel River samples did not indicate an increase in the arsenic and lead as the river flowed by the pile.



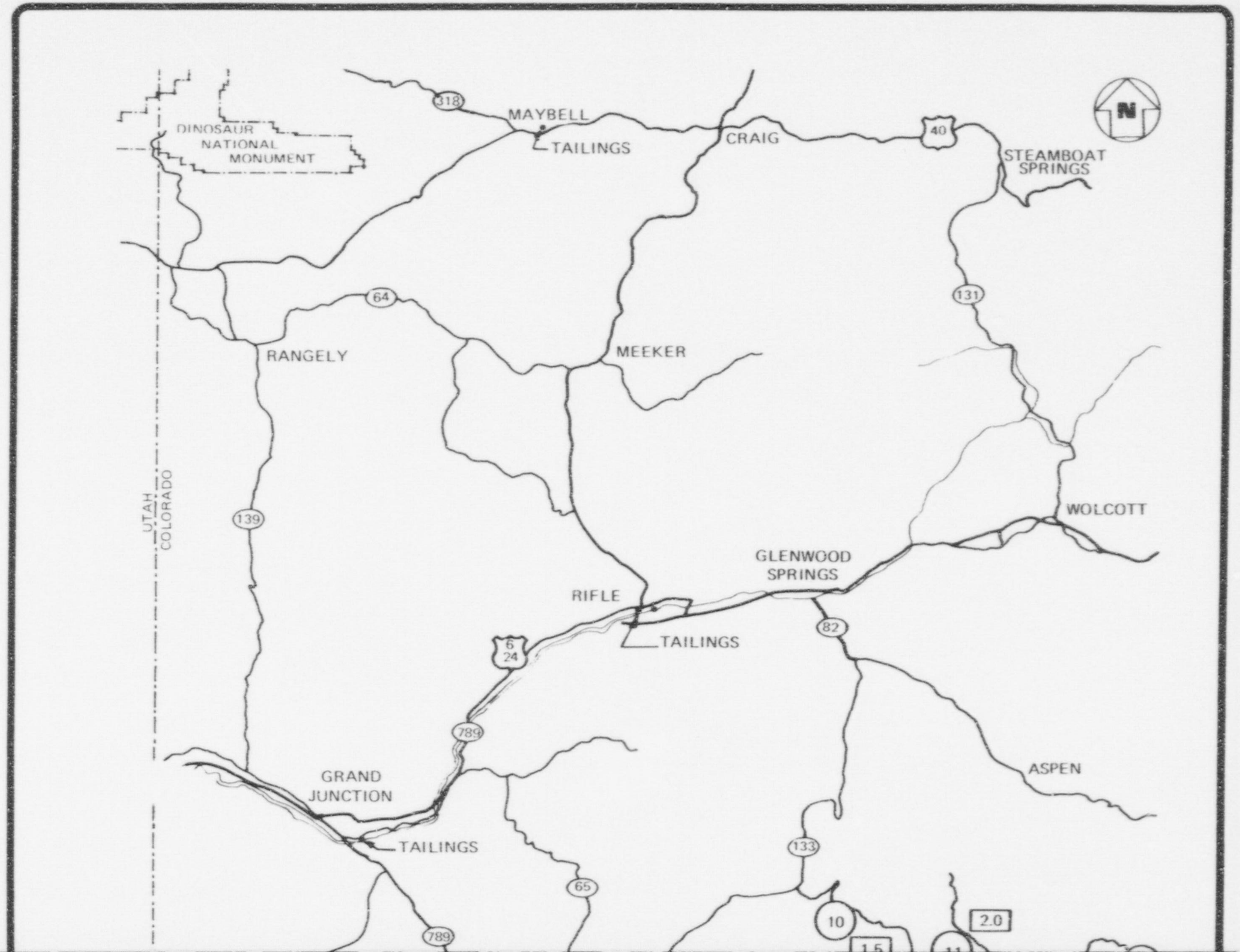
NOTE:

VERTICAL DIRECTION REPRESENTS ALPHA DECAY. HORIZONTAL DIRECTION INDICATES BETA DECAY. TIMES SHOWN ARE HALF LIVES. ONLY THE DOMINANT DECAY MODE IS SHOWN.

* ALSO GAMMA EMITTERS

FIGURE 3-1. RADIOACTIVE DECAY CHAIN OF URANIUM 238

130-07



DINOSAUR NATIONAL MONUMENT
318
MAYBELL
TAILINGS
CRAIG
40
STEAMBOAT SPRINGS
N
64
RANGELY
MEEKER
131
UTAH
COLORADO
139
WOLCOTT
GLENWOOD SPRINGS
RIFLE
TAILINGS
82
6
24
789
GRAND JUNCTION
TAILINGS
ASPEN
133
65
10
2.0
789

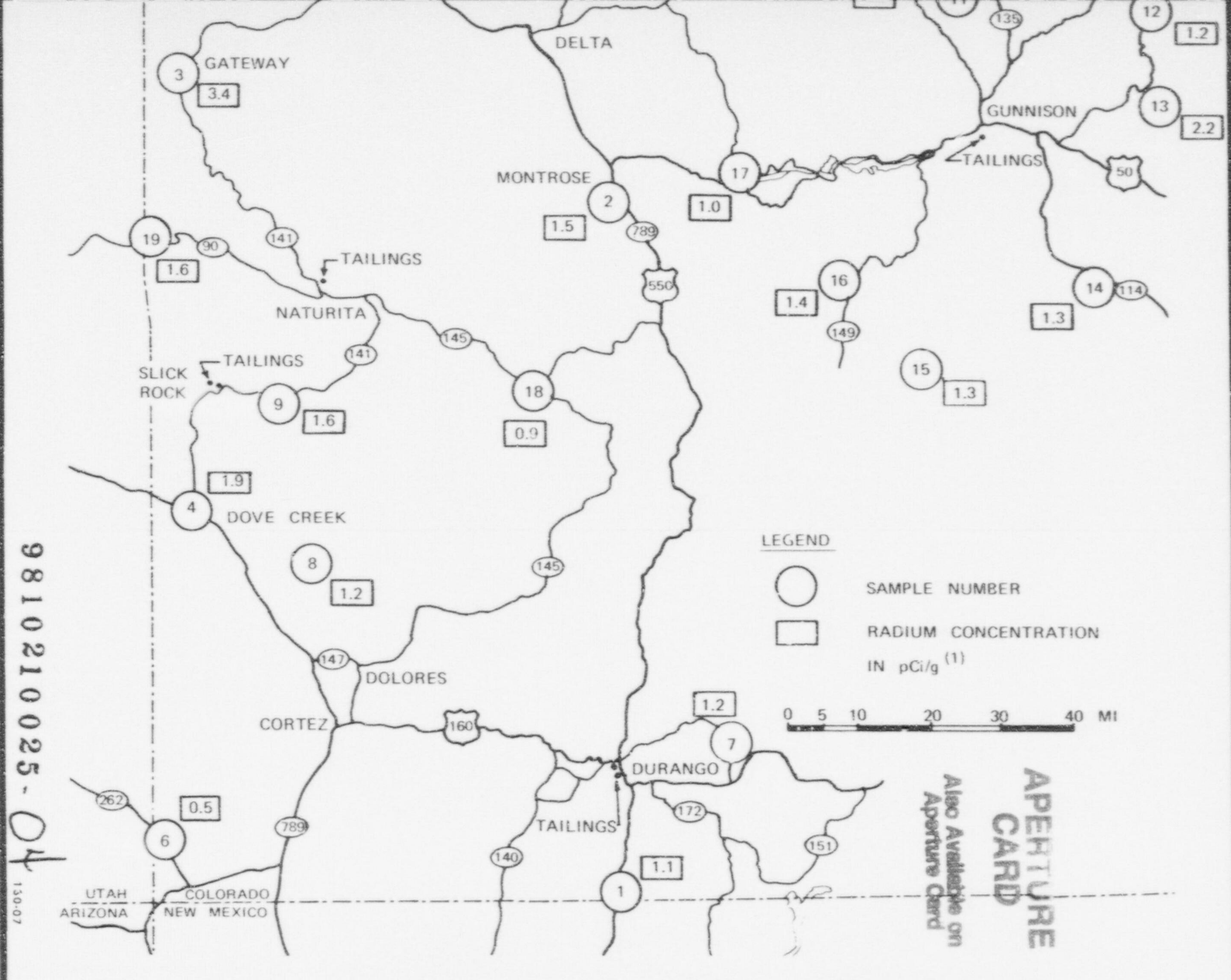


FIGURE 3-2. LOCATIONS FOR 226Ra BACKGROUND SAMPLES

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Ford, Bacon & Davis Utah Inc.

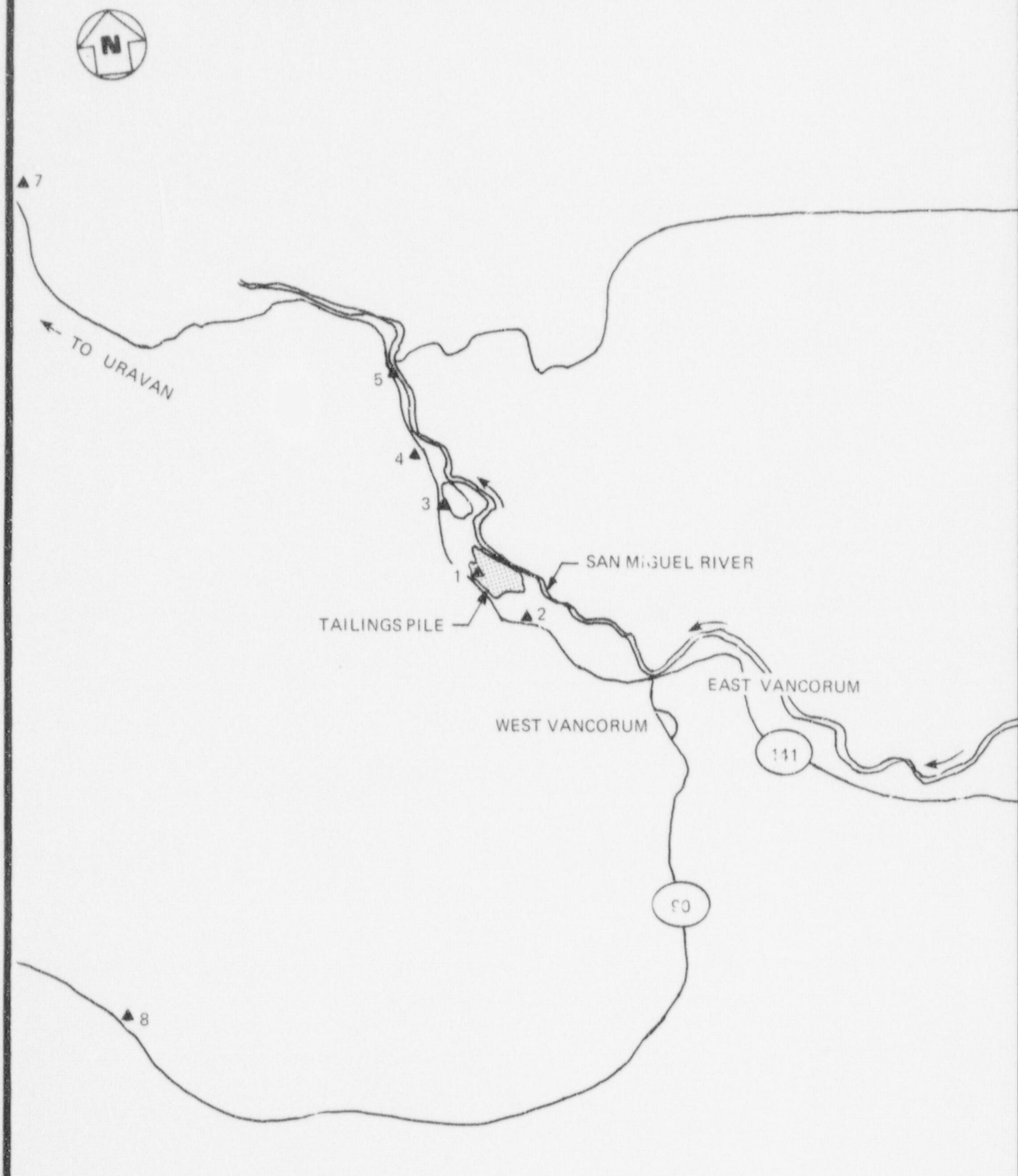
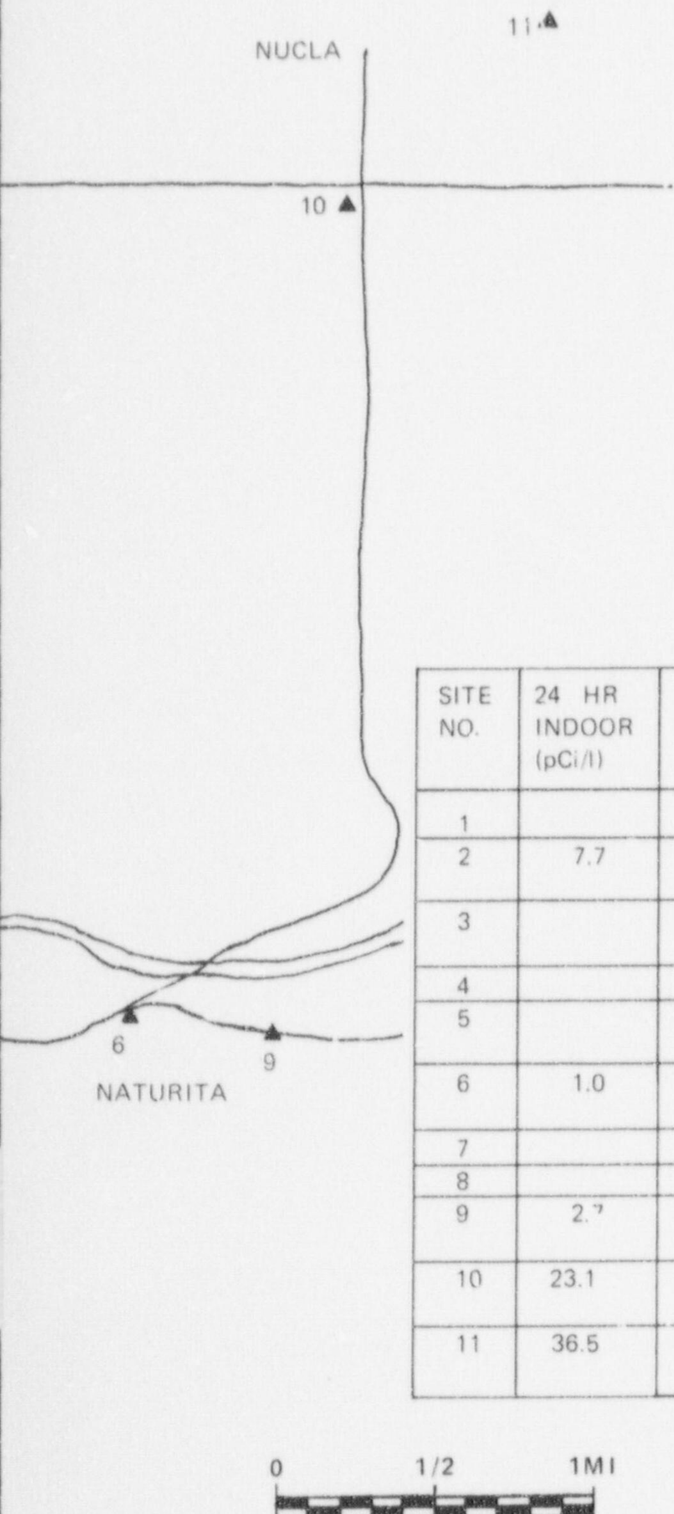


FIGURE 3-3 RADON CONCENTRATION IN VICINITY OF PILE



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SITE NO.	24 HR INDOOR (pCi/l)	24 HR OUTDOOR (pCi/l)	AVG WIND SPEED (KNOTS)	AVG WIND DIRECTION	LOCATION
1		252	2	W	ON PILE
2	7.7	8.8	8	SE	FOOTE MINERAL OFFICE 0.11 MI S OF PILE
3		15.0	2	W	RACE TRACK 0.17 MI N OF PILE
4		9.9	2	W	0.40 MI N OF PILE
5		6.2 5.7	2	SE	BRIDGE 0.91 MI N OF PILE
6	1.0	1.5*	6	SE	MOTEL 2.9 MI E OF PILE
7		2.4*	2	W	3.0 MI NW OF PILE
8		3.2*	2	W	3.0 MI SW OF PILE
9	2.7	1.7*	2	W	CHURCH 3.26 MI E OF PILE
10	23.1	2.7	8	SW	NUCLA TAILINGS LOCATION 25610
11	36.5	1.0*	8	SW	NUCLA TAILINGS LOCATION 25602

*BACKGROUND

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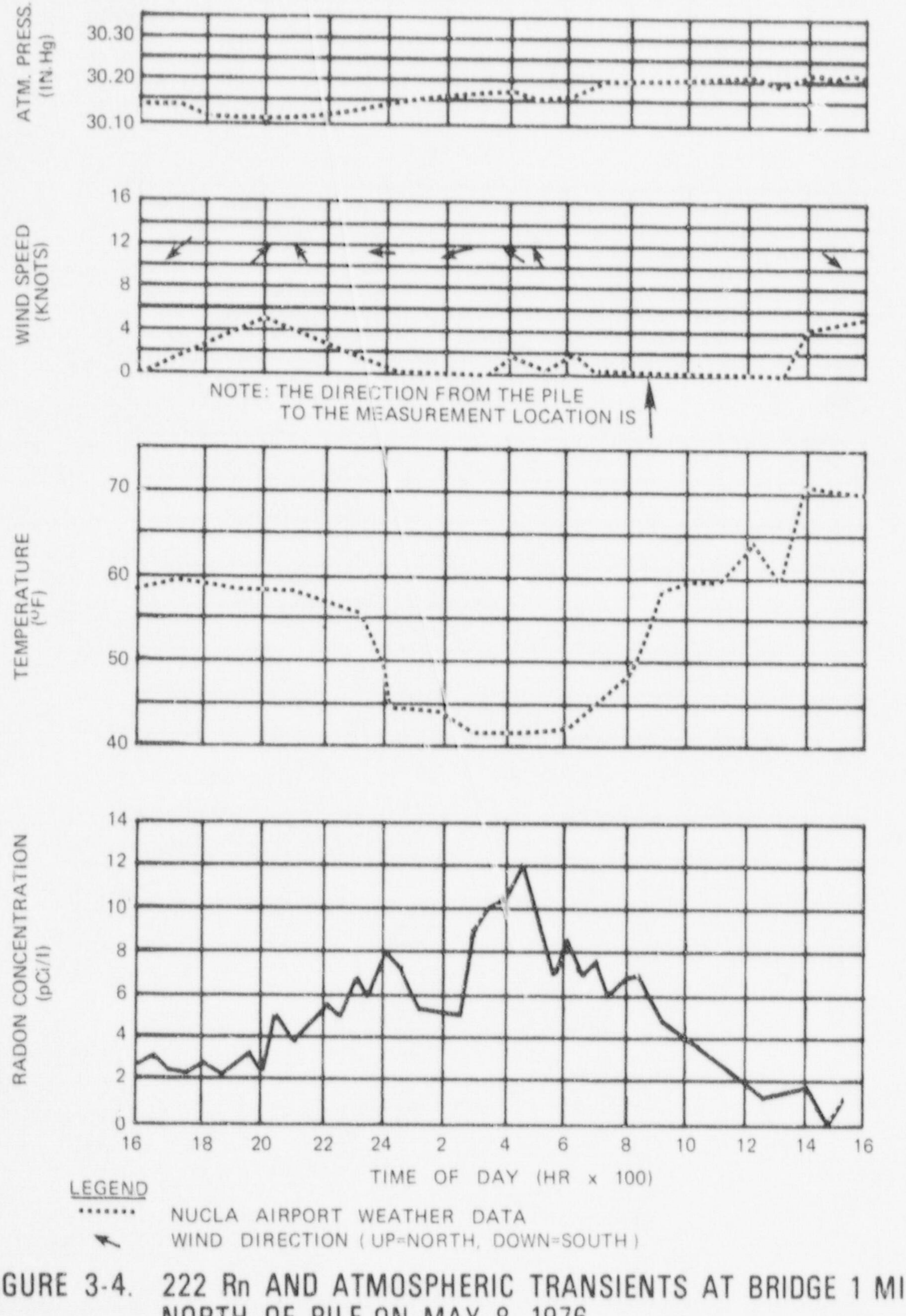

FIGURE 3-4. 222 Rn AND ATMOSPHERIC TRANSIENTS AT BRIDGE 1 MI NORTH OF PILE ON MAY 8, 1976

130-07

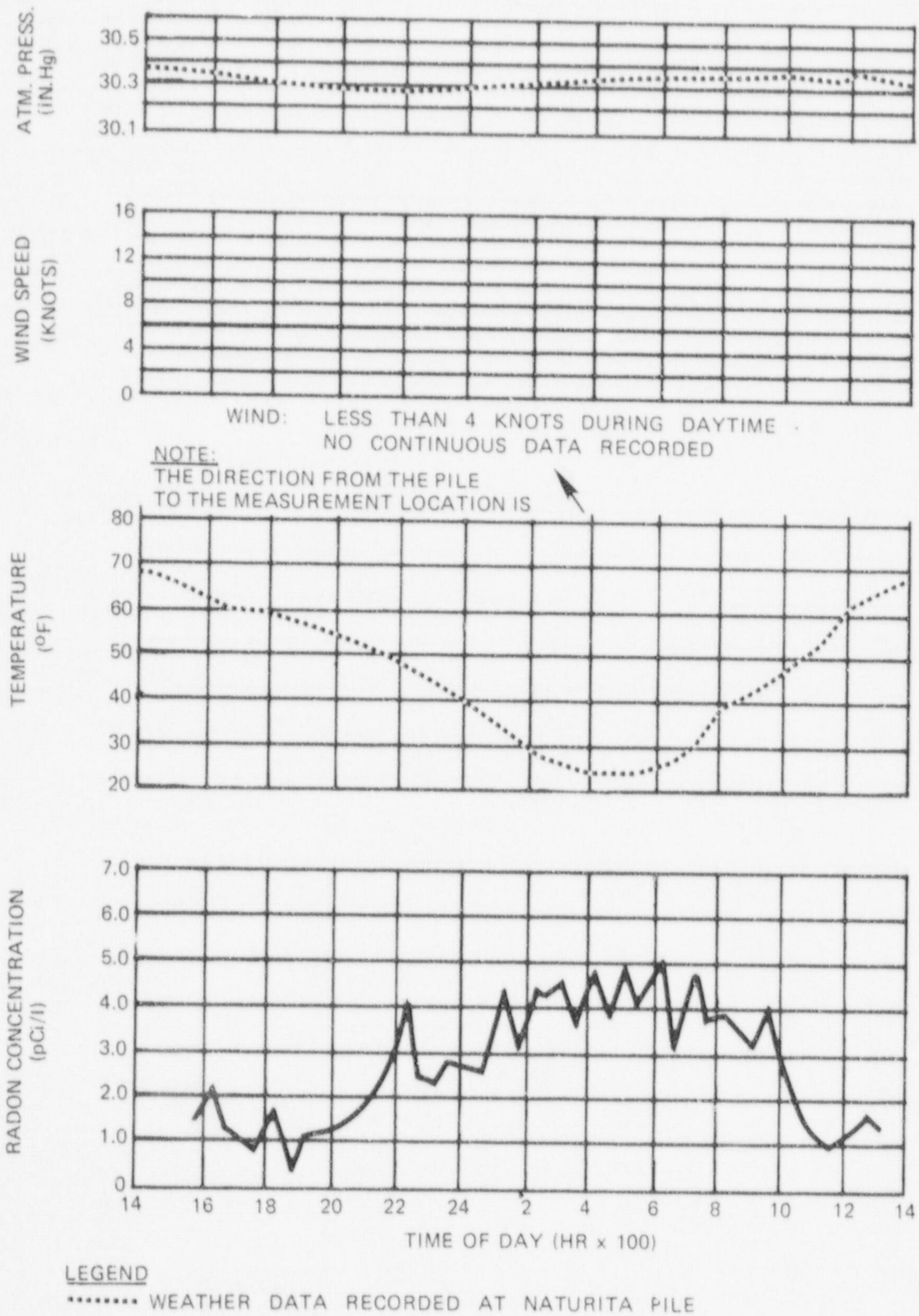

FIGURE 3-5. 222 Rn AND ATMOSPHERIC TRANSIENTS 3 MI NW OF PILE ON OCTOBER 8, 1976

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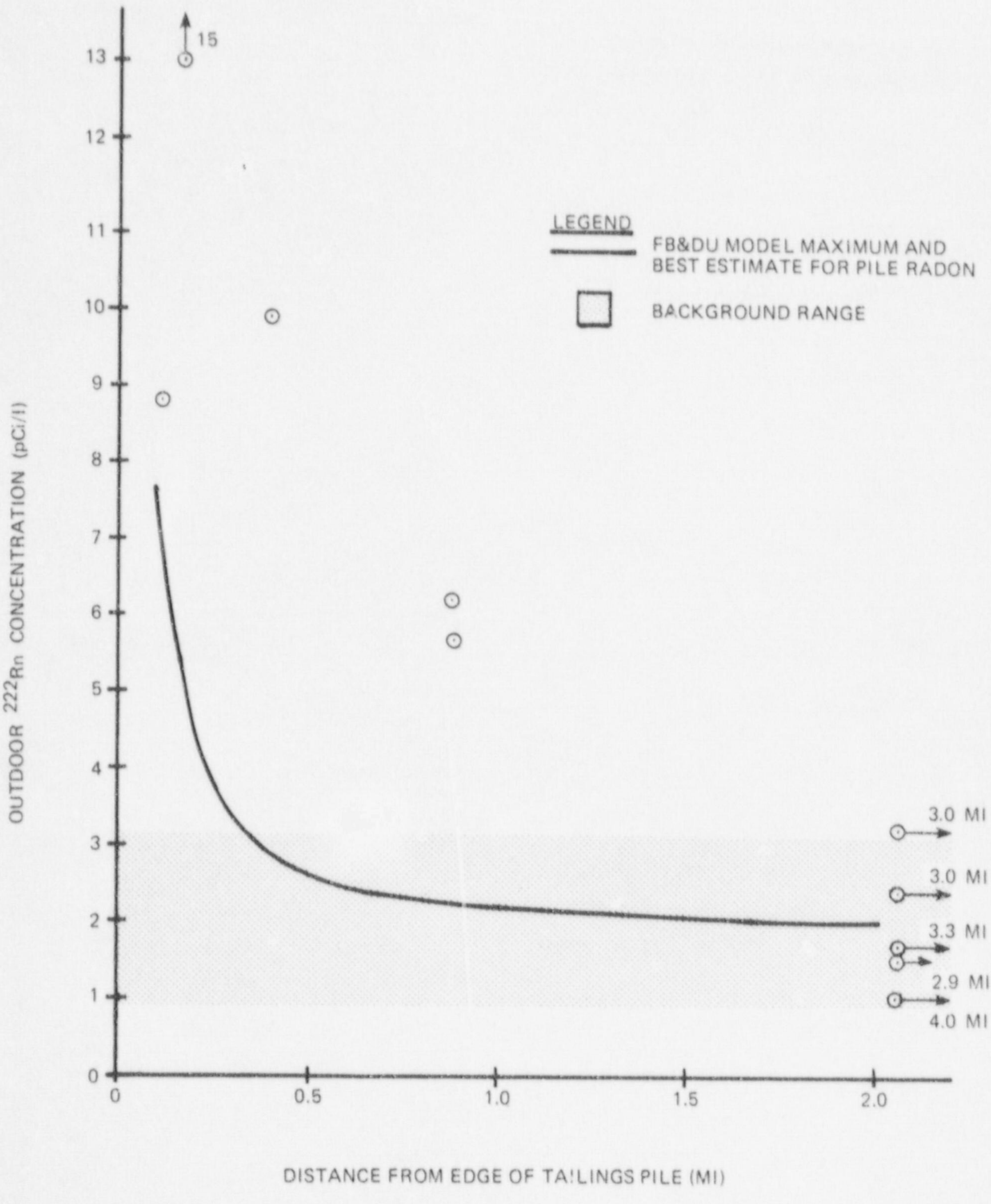
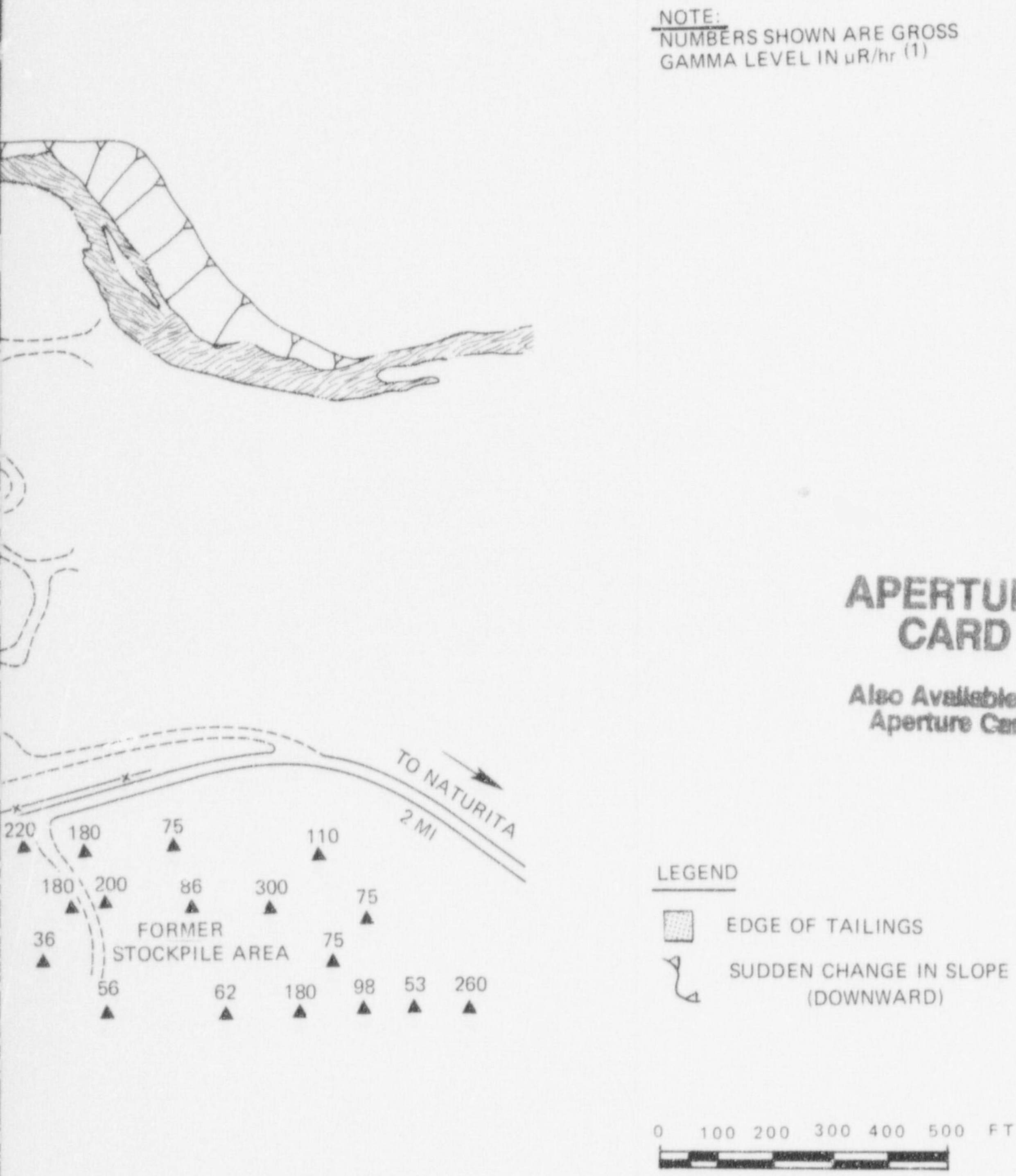


FIGURE 3-6. REDUCTION OF OUTDOOR 222Rn CONCENTRATION WITH DISTANCE FROM THE TAILINGS PILE

130-07

FIGURE 3-7. GAMMA LEVELS AT SITE 3 FT ABOVE GROUND



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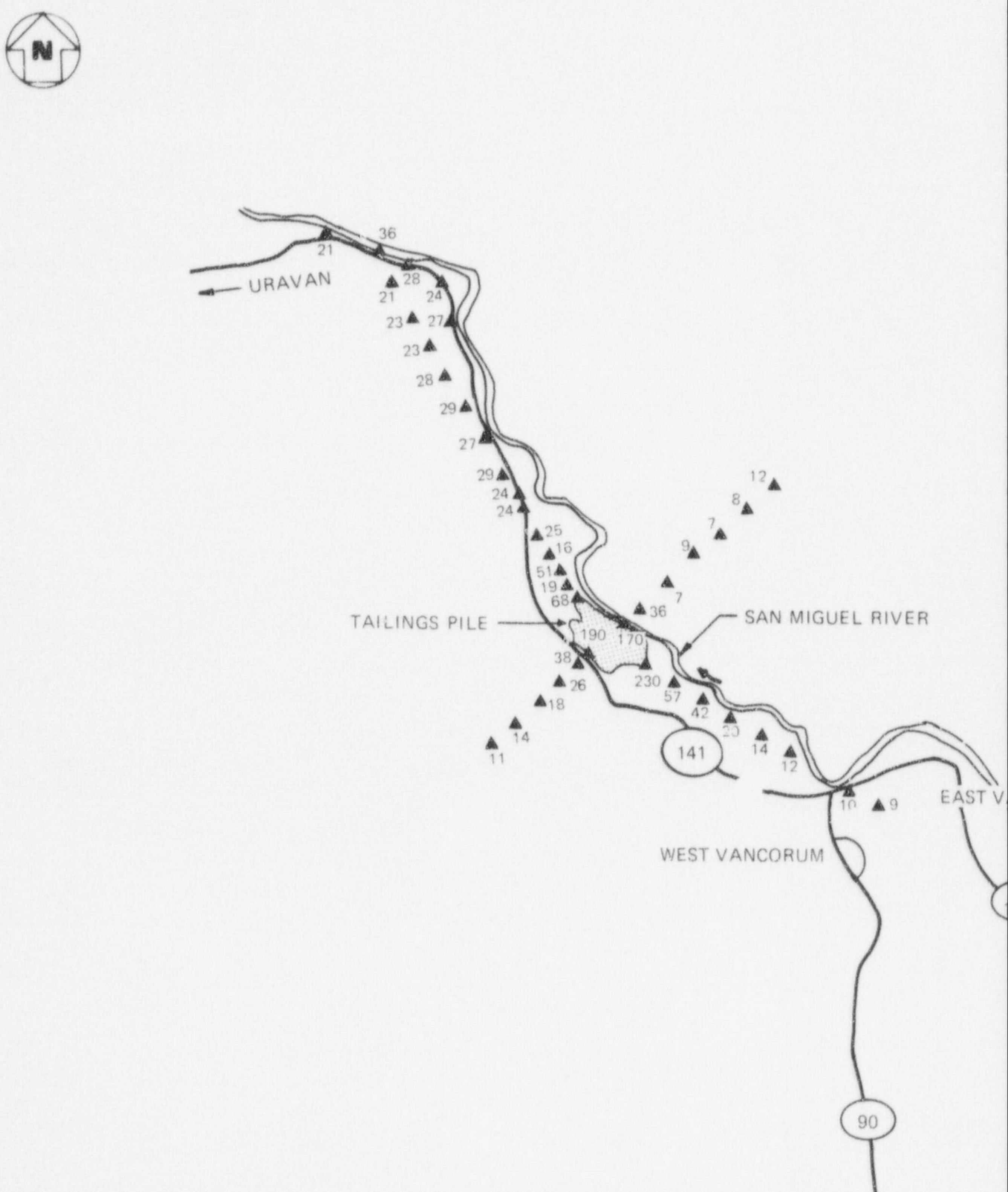
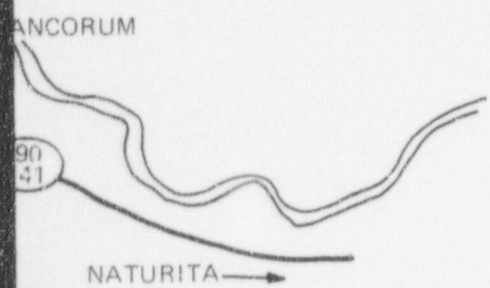


FIGURE 3-8. GAMMA LEVELS IN VICINITY 3 FT ABOVE GROUND



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NOTES:

1. NUMBERS SHOWN ARE GROSS GAMMA LEVELS IN μR/hr (1)

0 1/2 1 MI

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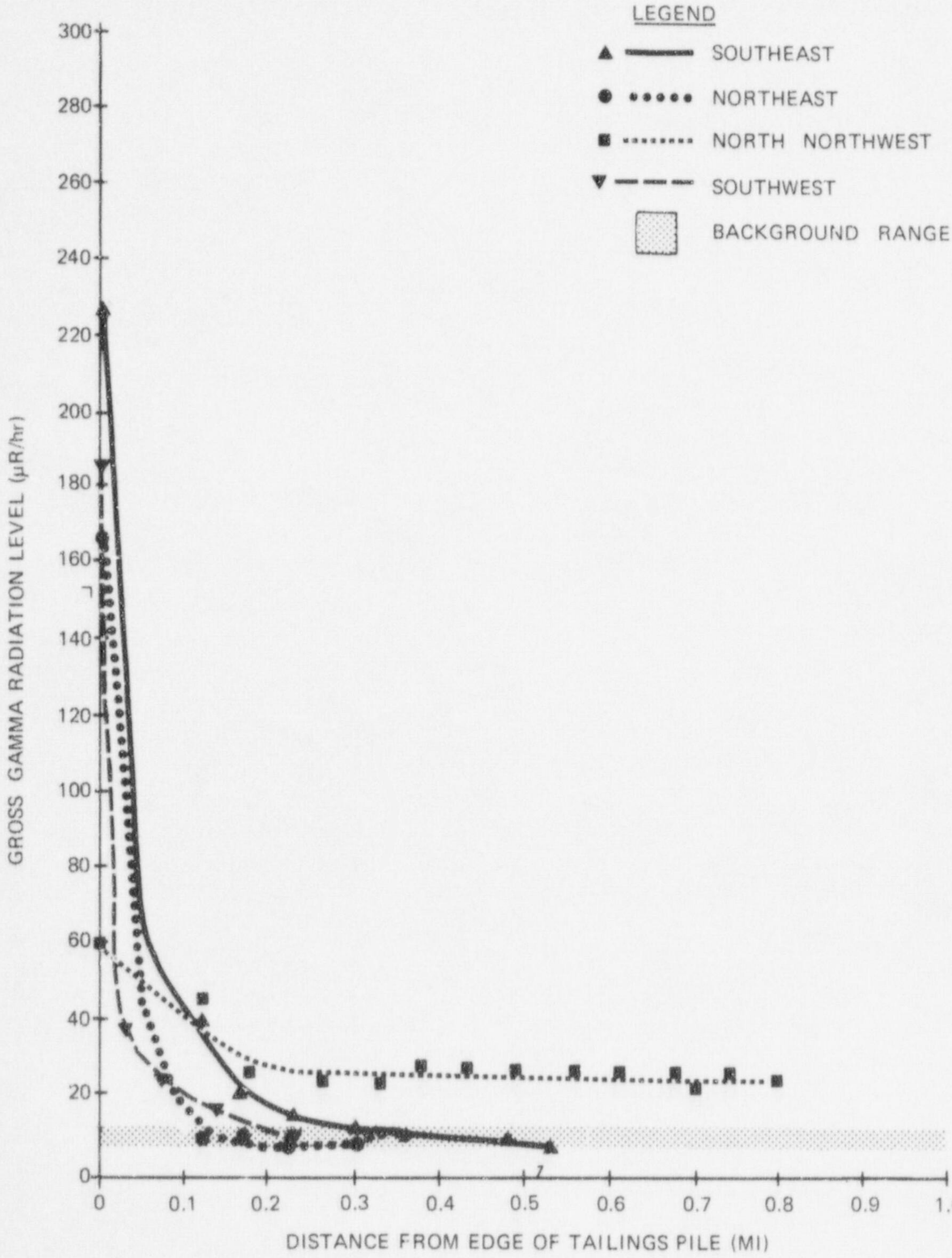


FIGURE 3-9. REDUCTION OF EXTERNAL GAMMA RADIATION LEVELS WITH DISTANCE FROM THE TAILINGS PILE

130-07

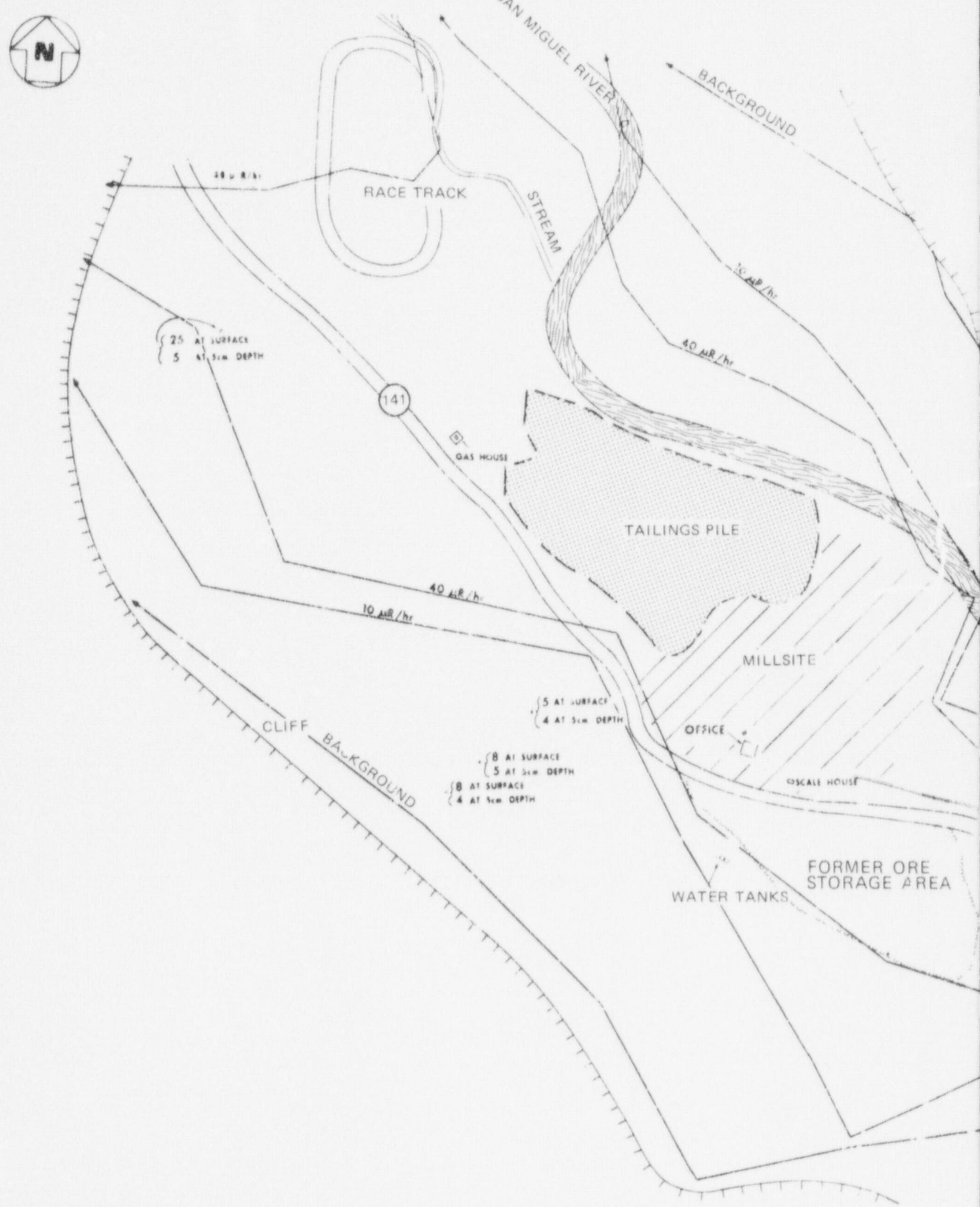
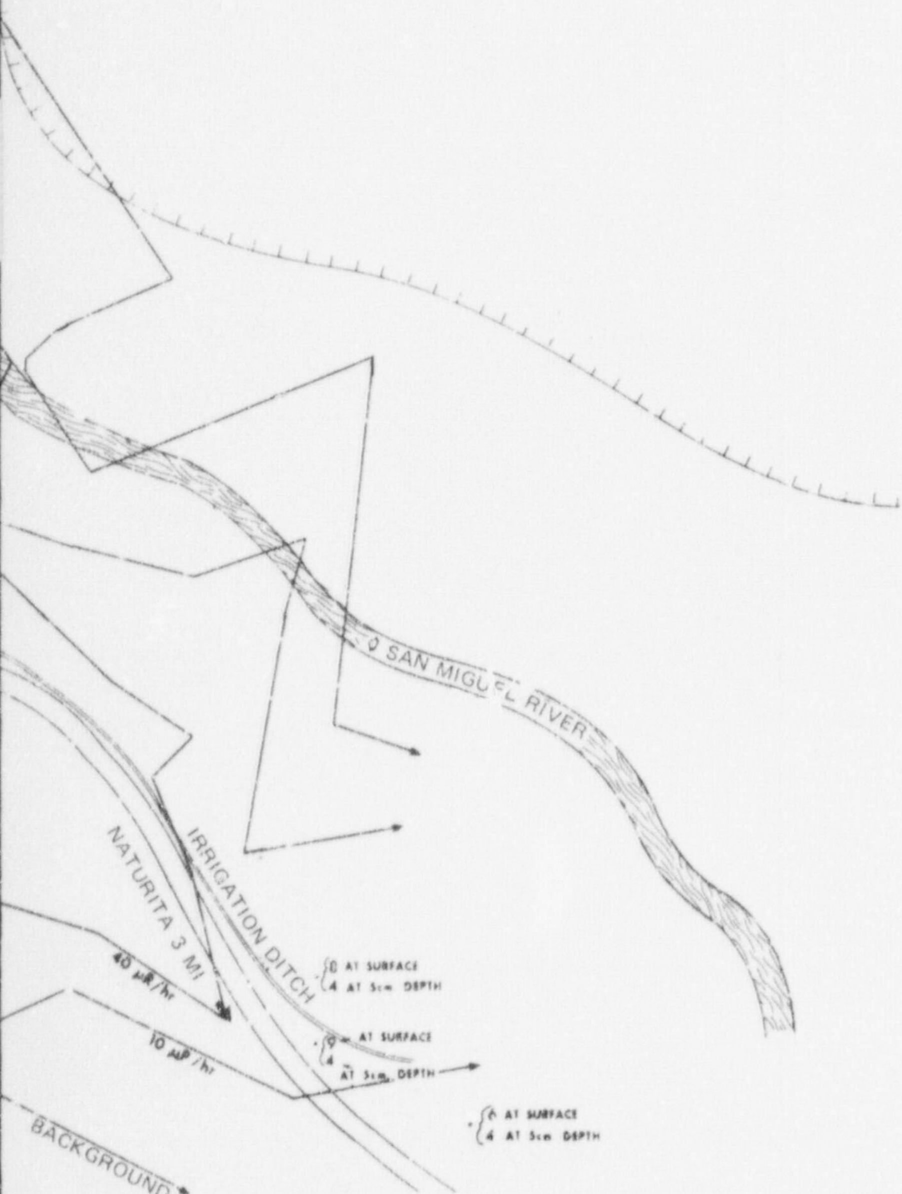


FIGURE 3-10. EPA GAMMA SURVEY SURROUNDING MILLSITE

NOTE:
REFERENCE: TECHNICAL NOTE ORP/LV-75-5, 'GAMMA RADIATION SURVEYS AT INACTIVE URANIUM MILLSITES', U S E P A , LAS VEGAS, NEVADA, AUG. 1975
FIG. 12 PAGE 59



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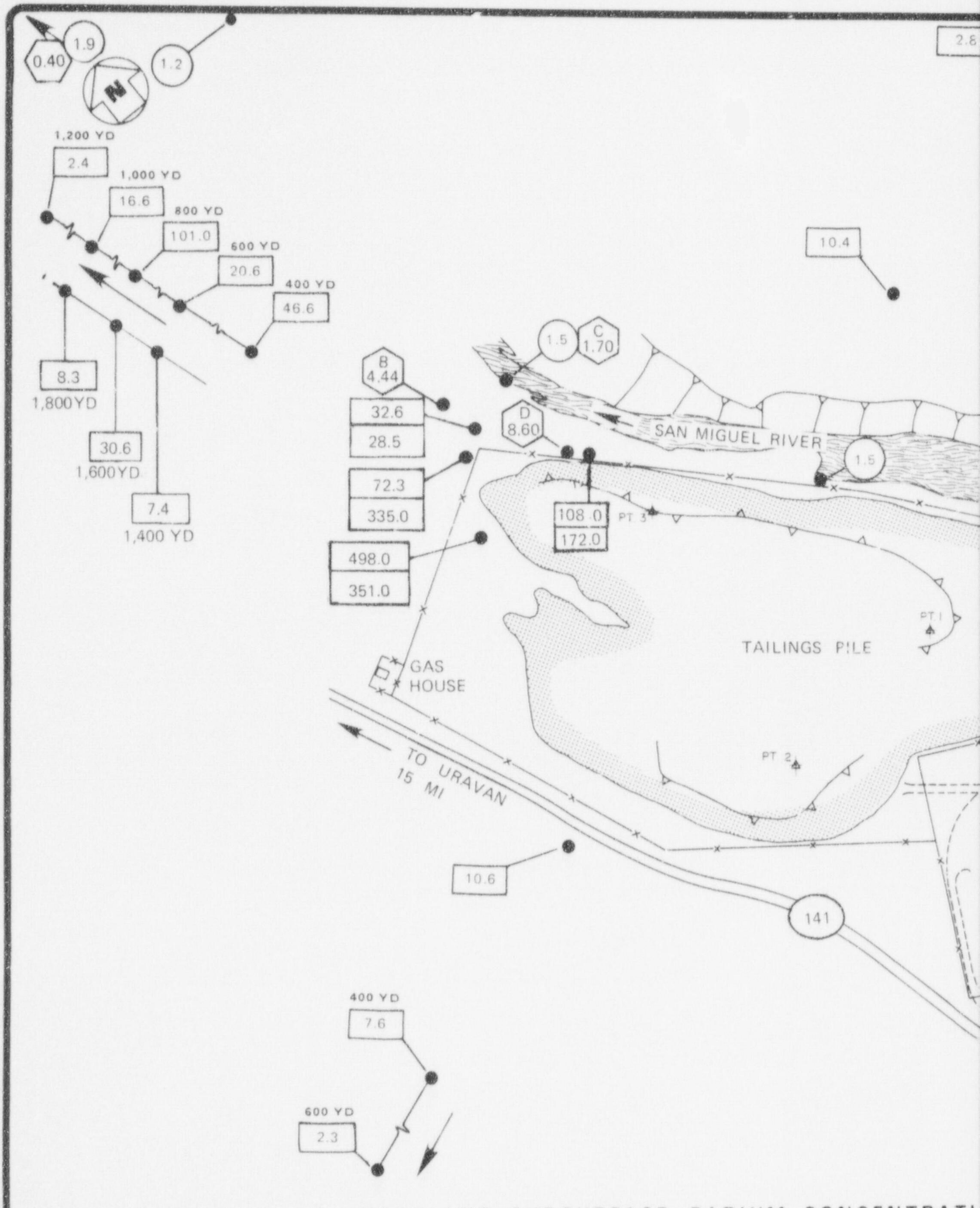
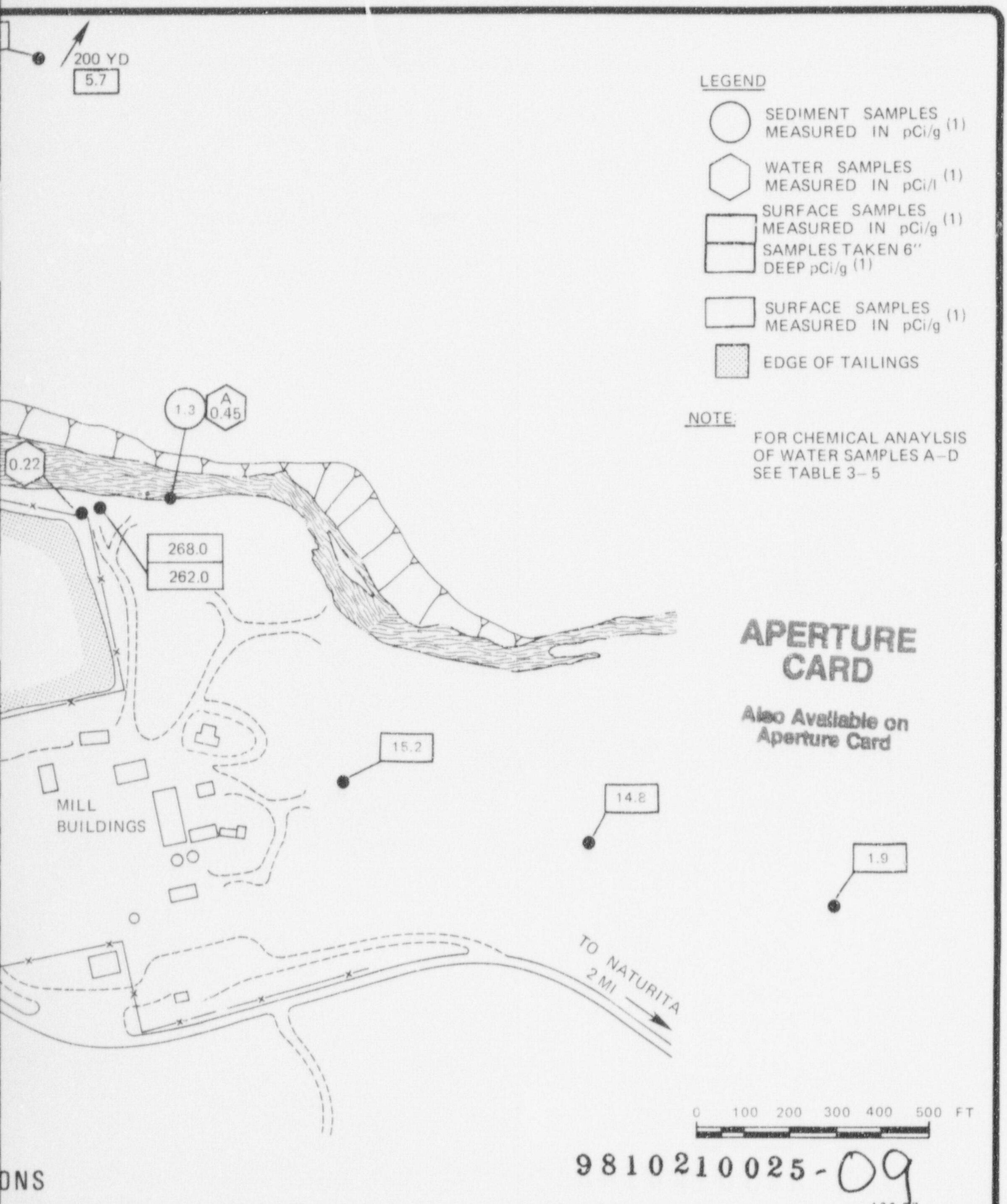


FIGURE 3-11. SURFACE AND SUBSURFACE RADIUM CONCENTRATI



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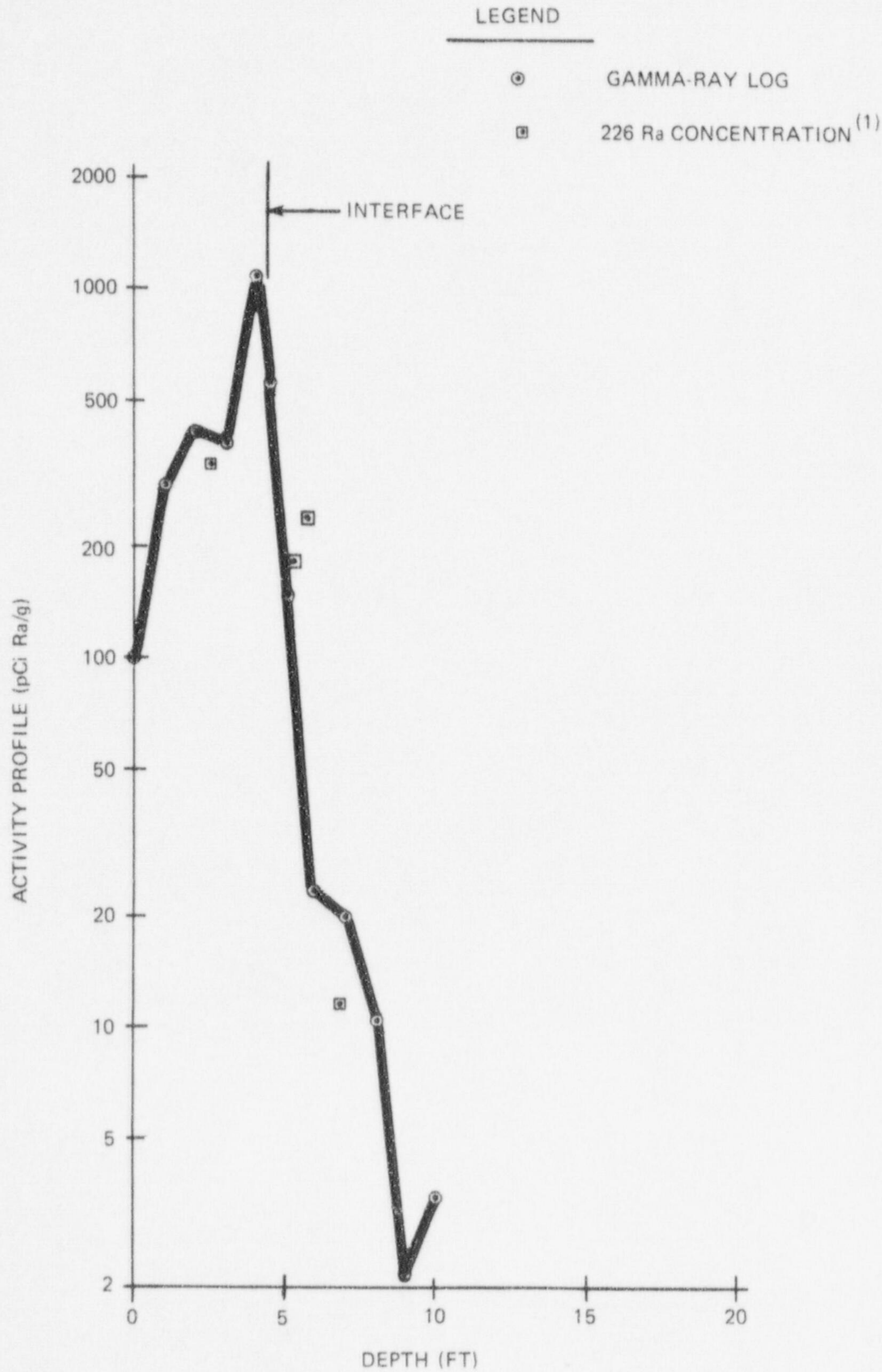

FIGURE 3-12. RADIOMETRIC PROFILE AT DRILL HOLE NC-2

130-07

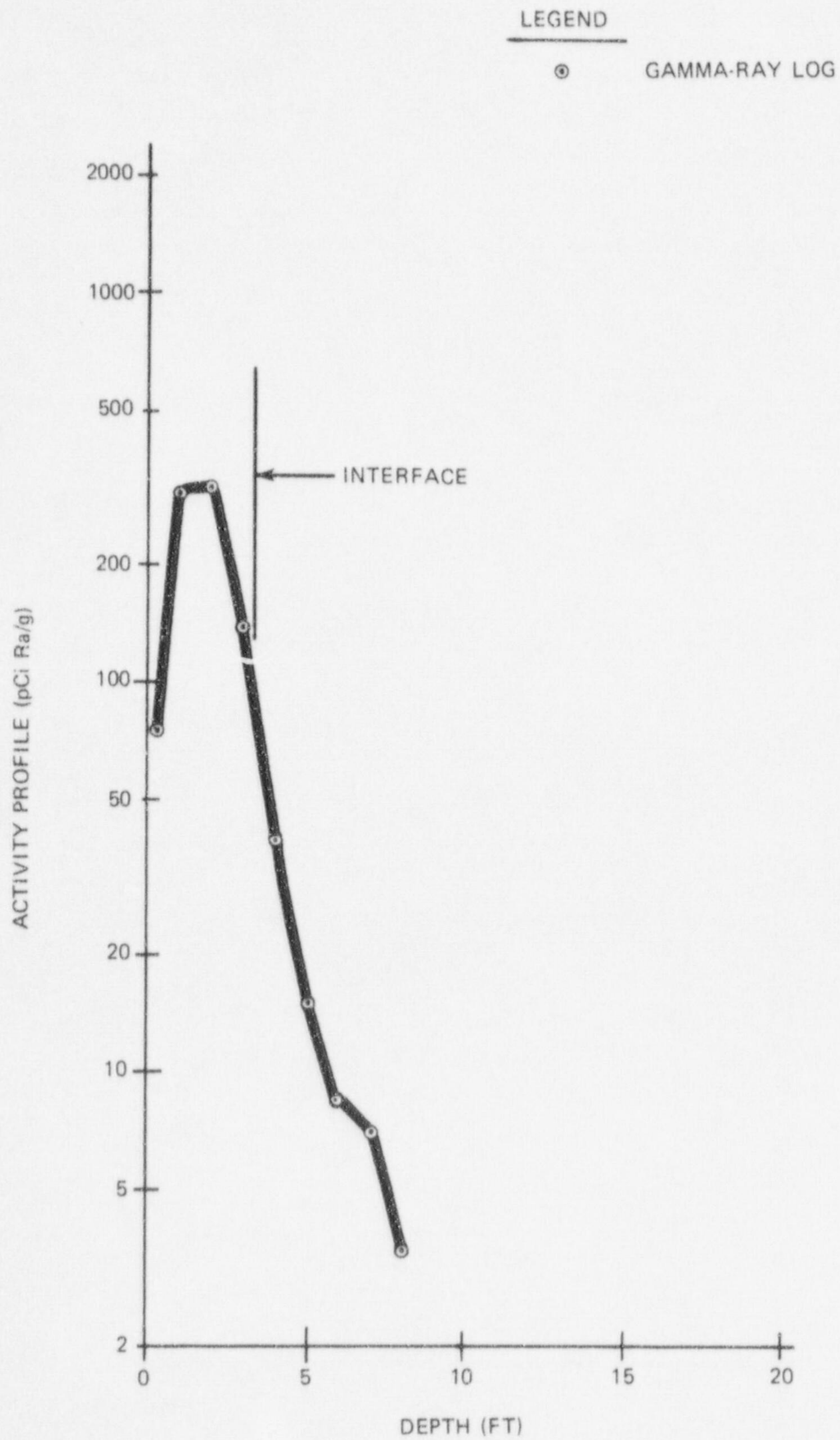

FIGURE 3-13. RADIOMETRIC PROFILE AT DRILL HOLE NC-4

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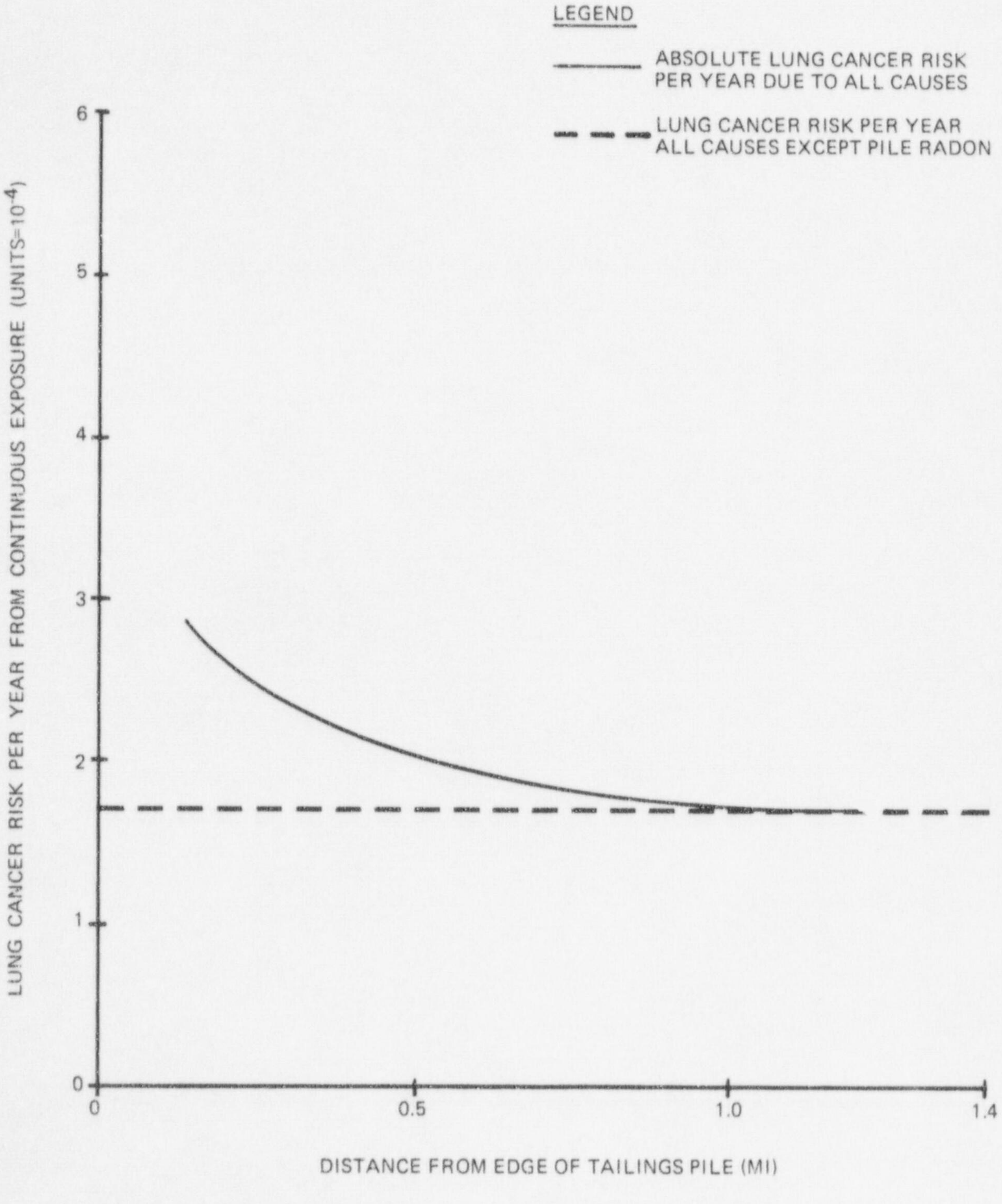

FIGURE 3-14. LUNG CANCER RISK FROM CONTINUOUS EXPOSURE TO RADON DIFFUSION

130-07

TABLE 3-1

NOTATIONS AND ABBREVIATIONS USED IN CHAPTER 3

Isotope - A particular type of element, differing by nuclear characteristics, identified by the atomic mass number given after the element name, e.g. radium-226.

Isotope Abbreviations:

^{238}U = Uranium-238

^{234}Th = Thorium-234

^{232}Th = Thorium-232

^{234}Pa = Protactinium-234

^{226}Ra = Radium-226

^{222}Rn = Radon-222

^{218}Po = Polonium-218

^{214}Pb = Lead-214

^{214}Bi = Bismuth-214

^{40}K = Potassium-40

Radiations:

alpha particle - helium nucleus; easily stopped with thin layers of material, all energy deposited locally.

beta particle - electron; penetrates about 0.2 g/cm^2 of material.

gamma rays - electromagnetic radiation; similar to X-rays, and highly penetrating.

Half-Life ($T_{1/2}$) - time required for half the radioactive atoms to decay.

TABLE 3-1 (Cont)

Working Level (WL)	- measure of potential alpha energy per liter of air from any combination of short-lived radon daughters (1 WL = 1.3 x 10^5 MeV of alpha energy).
One Working Level Month (WLM)	- WLM-Exposure to air containing a RDC of 1 WL for a duration of 170 hr.
Roentgen (R)	- that quantity of gamma radiation which yields a charge deposition of 2.58 x 10^{-4} coul/kg air. This is equal to the energy deposition of 88 ergs/g of dry air or 93 ergs/g of tissue.
μR/hr	- 10^{-6} Roentgen/hr.
Rad	- energy deposition of 100 ergs/g of material
Picocurie (pCi)	- unit of activity (1 pCi = 0.037 radioactive decays/sec or 2.2/min).
MeV	- unit of energy - 1 MeV = 1.6 x 10^{-6} erg.
Rem	- unit of energy deposition in man. 1 rem = 1 rad x quality factor. The quality factor = 20 for alpha particles.

TABLE 3-2

BACKGROUND RADIATION SOURCES IN SOIL FROM SOUTHWEST COLORADO

Isotope (Decay Chain)	Average Value (pCi/g)	Range (pCi/g)
^{226}Ra (^{238}U)	1.48±0.63	0.54-3.4
^{232}Th (^{232}Th)	1.11±0.32	0.10-1.46

TABLE 3-3

RADON EXHALATION FLUX FROM THE NATURITA TAILINGS

Sample	Location[a]	Radon Flux (pCi/m^2-sec)
1 (RNC-1)	At drill hole NR-10	2540
2 (RNC-2)	At drill hole NR-12	1220
3 (RNC-3)	At control point #2	1240
4 (RNC-4)	At control point #1	760
5 (RNC-5)	At control point #3	1470

[a]3-hr samples taken on May 10, 1976

TABLE 3-4

ESTIMATED HEALTH IMPACT FROM NATURITA TAILINGS FOR AN AREA 0-4 MILES FROM TAILINGS EDGE

Time Period	Population (Persons)	Total Pile-Induced RDC Health Effects/yr	Background RDC Health Effects/yr
1976	1,900	0.004	0.17
2001 (Static)	1,900	0.004	0.17
2001 (2% growth rate[a])	2,500	0.005	0.22
2001 (4% growth rate[a])	3,200	0.007	0.29
25-yr Cumulative Effect		Pile Induced RDC	
Static population		0.10	4.3
2% growth rate[a]		0.12	5.1
4% growth rate[a]		0.14	6.1

[a]The growth rate decreases linearly with time to zero in 25 yr.

TABLE 3-5

CHEMICAL ANALYSES OF NATURITA WATER SAMPLES (mg/l)

Sample[a]	As	Ba	Cd	Cr	V	Fe	Pb	Se
A - San Miguel River 100 yd upstream from pile	<0.001	<0.001	<0.001	0.05	<0.01	0.84	0.031	0.009
B - Standing water in ditch north edge of pile	0.327	0.034	<0.001	<0.001	7.47	0.73	0.075	0.165
C - San Miguel River 100 yd downstream from pile	<0.001	0.048	<0.001	0.100	<0.01	1.20	0.026	0.012
D - Standing water in ditch north edge of pile	0.028	0.012	<0.001	<0.001	0.42	1.40	0.025	0.043
EPA Interim Drinking Water Standards[b]	0.05	1.0	0.01	0.05	--	0.3[c]	0.05	0.01

[a]See Figure 3-11 for locations

[b]Federal Register, Dec 24, 1975

[c]Recommended limit from Manual for Evaluating Public Drinking Water Supplies, U.S. Public Health Service, 1969

CHAPTER 3 REFERENCES

1. F. F. Haywood, et al; "Assessment of Radiological Impact of the Inactive Uranium Mill Tailings Pile at Naturita, Colorado"; ORNL (in preparation).

2. M. E. Wrenn, H. Spitz, and N. Cohen; "Design of a Continuous Digital-Output Environmental Radon Monitor"; IEEE Transactions on Nuclear Science; Vol NS-22; Feb 1975.

3. D. T. Oakley; "Natural Radiation Exposure in the United States"; EPA Report ORP/SIO 72-1; Jun 1972.

4. R. J. Countess; "^{222}Rn Flux Measurement with a Charcoal Canister"; Health Physics; Vol 31; p. 455; 1976.

5. D. H. Slade, ed; Meteorology and Atomic Energy 1968; TID-24190; AEC; Jul 1968.

6. R. L. Douglas and J. M. Hans, Jr.; "Gamma Radiation Surveys at Inactive Uranium Mill Sites"; Technical Note ORP-LV-75-5; EPA; Office of Radiation Programs; Las Vegas, Nevada; Aug 1975.

7. "Radium-226, Uranium, and other Radiological Data Collected from Water Quality Surveillance Stations Located in Colorado, Utah, New Mexico, and Arizona"; 8SA/TIB-24; EPA, Region VIII; Jul 1973.

8. Office of the U.S. Surgeon General, U.S. Department of Health, Education, and Welfare; Jul 1970.

9. "Radiological Criteria for Decontamination of Inactive Uranium Mill Sites"; EPA; Office of Radiation Programs; Washington, D.C.; Dec 1974.

10. F. F. Haywood, et al; "Assessment of Radiological Impact of the Inactive Uranium Mill Tailings Pile at Salt Lake City"; (in preparation).

11. A. J. Breslin and H. Glauberman; "Uranium Mill Tailings Study"; AEC Technical Memorandum; HASL-64-14; Jul 1964.

12. "Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Vitro Site, Salt Lake City, Utah"; GJT-1; FB&DU; Apr 1976.

13. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation"; Report of Advisory Committee on Biological Effects of Ionizing Radiation; NAS, National Research Council; Nov 1972.

14. W. Jacobi; "Interpretation of Measurements in Uranium Mines: Dose Evaluation and Biomedical Aspects"; NEA Specialist Meeting; Elliot Lake, Canada; Oct 4-8, 1976.

15. R. H. Johnson, Jr., D. E. Bernhardt, N. S. Nelson, and H. W. Calley, Jr.; "Assessment of Potential Radiological Health Effects from Radon in Natural Gas"; EPA-520/1-73-004; EPA; Nov 1973.

16. J. Sevc, E. Kunz, and V. Placek; "Lung Cancer in Uranium Miners and Long-Term Exposure to Radon Daughter Products"; Health Physics; Vol 30; p. 433; 1976.

17. R. M. Fry; "Radon and Its Hazards"; NEA Specialist Meeting; Elliot Lake, Canada; Oct 4-8, 1976.

18. "Health Effects of Alpha-Emitting Particles in the Respiratory Tract"; Report of the Advisory Committee on the Biological Effects of Ionizing Radiation: EPA/ORP; EPA-520-4-76-013; Washington, D.C.; Oct 1976.

19. Vital Statistics of the U.S.; Vol II; Mortality; National Center for Health Statistics; HEW; 1968.

CHAPTER 4

SOCIOECONOMIC AND LAND USE IMPACTS

CHAPTER 4

SOCIOECONOMIC AND LAND USE IMPACTS

This chapter describes the population concentrations and land use in the vicinity of the Naturita tailings. The basis for estimating population growth for the health effects calculations is also discussed. The boundaries of Montrose County are shown in Figure 4-1.

4.1 SOCIOECONOMIC BACKGROUND

The closest population concentration with commercial activity is Naturita, 3 mi southeast of the pile. Colorado highways 143, 141, and 90 service the area. Two other small communities, East and West Vancorum, are located along Colorado highway 141 approximately halfway between Naturita and the tailings. In addition, the community of Nucla is located approximately 5 mi northeast of the pile. The city of Montrose is the county seat of Montrose County, in which Naturita is located. The demographic and economic conditions of Naturita can be projected by extrapolating statistical data obtained for the four census records of 1940 through 1970.[1] The population of Naturita and its environs has been highly dependent upon the activities of the area's uranium mining industry. It experienced substantial growth in the 1940's and 1950's, a decline in growth during the 1960's, and no noticeable growth in the 1970's. Montrose County has experienced virtually no population change over the past decades, except for an increase during the 1950's. These population fluctuations are in contrast to the constant, smooth growth exhibited by the population of the State of Colorado. The median age of Montrose County declined from 29.1 in 1940 to 26.6 in 1960, and then increased to 29.1 in 1970. The male percentage of the population of Naturita decreased from 59.3% in 1940 to 51.9% in 1970.

Ethnically, the population of Naturita is dominantly Caucasian; 2% are Indian. Educational attainment and median income are lower than the state's averages. Most workers now are employed as farmers, clericals, craftsman and service providers, but farmers and farm laborers show a consistent decline in both real numbers and percent of the total. Today, Naturita is a small community in a county whose economy is based on mining and agriculture.

4.2 POPULATION ESTIMATES

The 1970 census figures show a population of 820 residents at Naturita and 18,366 county residents. A modified population base is used in the health effects assessment (see Chapter 3).

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(1) See end of chapter for references.

Residents within 4 mi of the tailings pile were estimated at 1,900 in 1973, and no growth has been assumed since then. As seen in Figure 4-2, the major concentrations of population are southeast of the tailings.

Several factors must be considered in determining population projections and future growth patterns for the Naturita area. First, the water available to support growth is severely limited. Any population growth sustained by agriculture and industry will restrict growth further, because water which might otherwise be used for domestic and commercial purposes would be needed for irrigation and industry. Second, tourism cannot be expected to develop in the area. Third, the isolation of the area from air, rail, and land transportation severely hampers development. Finally, development of the mineral resources remaining in the area can be expected to increase in the near term, then become constant and eventually decline.

Considering these factors, three rates of growth were employed. The highest assumes a 2.0% annual growth rate. This is approximately the growth rate of the Mountain States for 1974. The second rate is 0.8%, which is the current growth rate for the United States. The third rate is an annual decline in population by -1.6%, which is an extension of the population trend from 1960 to 1970.

The population projection factors are presented in Figure 4-3. The curves represent three steady rates of growth and three declining rates of growth beginning in 1970. To obtain the population projections for a given year, the appropriate 1970 population is multiplied by the population factors for the year in question.

Assumptions of a steady rate of growth may be highly unrealistic. For the reasons given above, the rate of growth could decline and approach zero by some future date. Also presented in Figure 4-3 are the population projection factors for a steady 10-yr growth rate followed by a declining rate to zero growth at 25 yr. This is referred to as a "declining rate of growth".

The lowest constant rate (-1.6%) indicates there will be 0.6 times as many inhabitants in the year 2000 and 0.4 times as many in 2025 as in 1970. If the rapid constant rate (2.0%) is assumed, there will be 1.3 persons in the year 2000 and 3 persons in the year 2025 for every person now there. This most rapid constant rate provides results which may be tenable for the short run; however the unavailability of water, the lack of transportation facilities, and the long distance from other population centers make sustaining this rate highly unlikely. If the declining growth rate is assumed, then by the year 2000 there will be 1.7 times as many residents for the 4% rate, and 1.3 times as many using the 2% declining rate of growth.

In calculating the effect of the uranium mill tailings on health, three rates were used: a static population, 2%, and 4% declining rate of growth.

4.3 LAND USE

The land ownership in the area of the tailings is shown in Figure 4-4. A good portion of the property surrounding the Naturita site is under management of the Bureau of Land Management. Virtually all the land near the Naturita tailings is devoted to low-density grazing and other agriculture uses. As shown in Figure 4-2, East Vancorum, West Vancorum and Naturita are residential concentrations near the pile. There are 34 occupied residential units at West Vancorum, 4 occupied units at East Vancorum, and many abandoned units and trailer sites at both locations. The only commercial and service facilities are located in Naturita. The millsite adjacent to the pile is leased and operated as an ore buying station by General Electric Company.

4.4 IMPACT OF THE TAILINGS ON LAND VALUES

The 160 acres of private land northeast of the river are assessed at \$8.33/acre with improvements, and the 180 acres of private land east of the river are assessed at \$7.59/acre with improvements. The land between the tailings site and Colorado highway 141 is on record as belonging to Foote Mineral Company and is assessed at \$28,533.33 with improvements. In general, the land surrounding the site has a market value of about \$1,000/acre.

The presence of the tailings at the Naturita site restricts the use of the site itself. However, the loss of grazing or crop land is minimal and the presence of the tailings has only slightly affected the land use and land values of surrounding property.

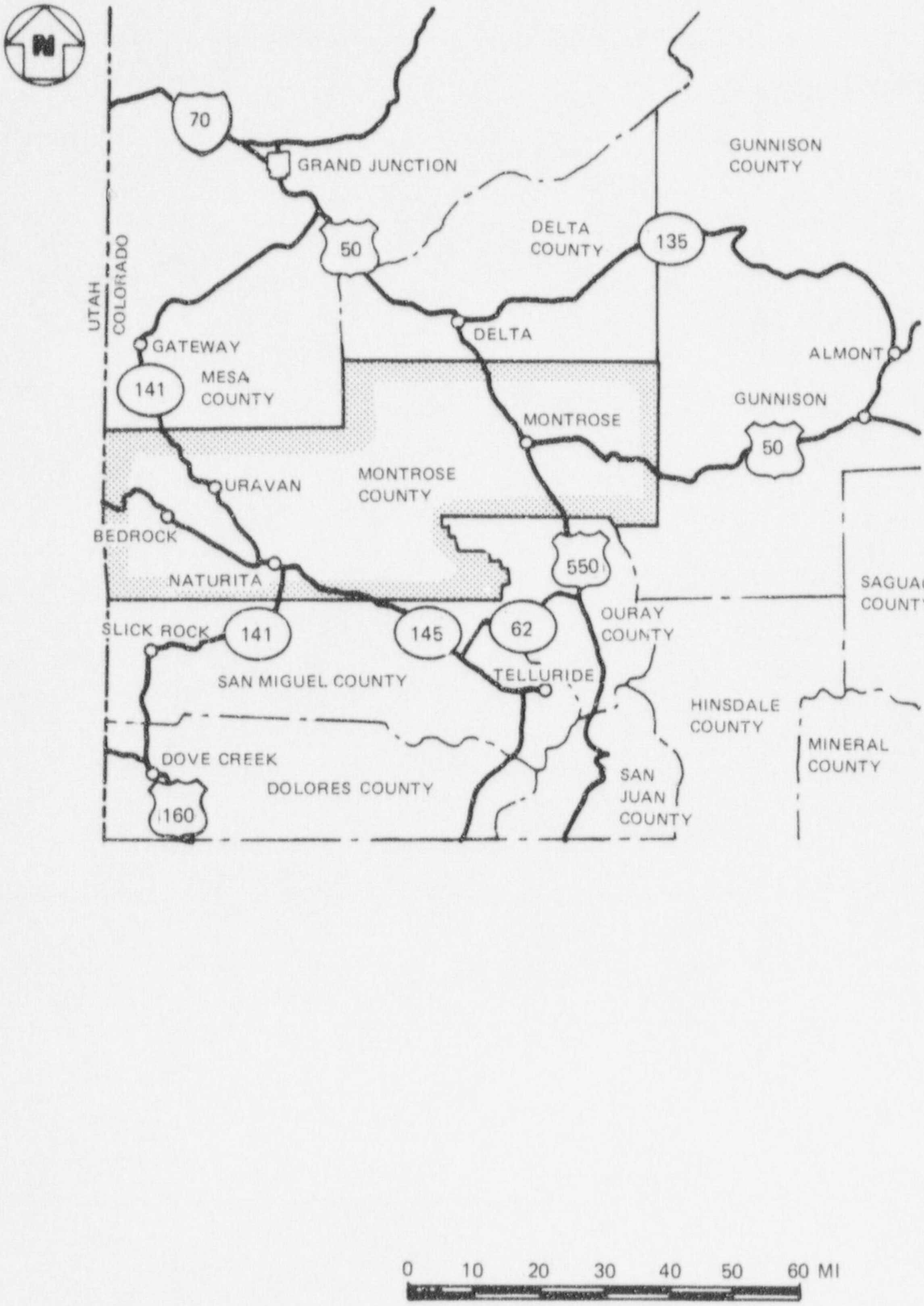

FIGURE 4-1. MAP OF MONTROSE COUNTY BOUNDRIES

130-07

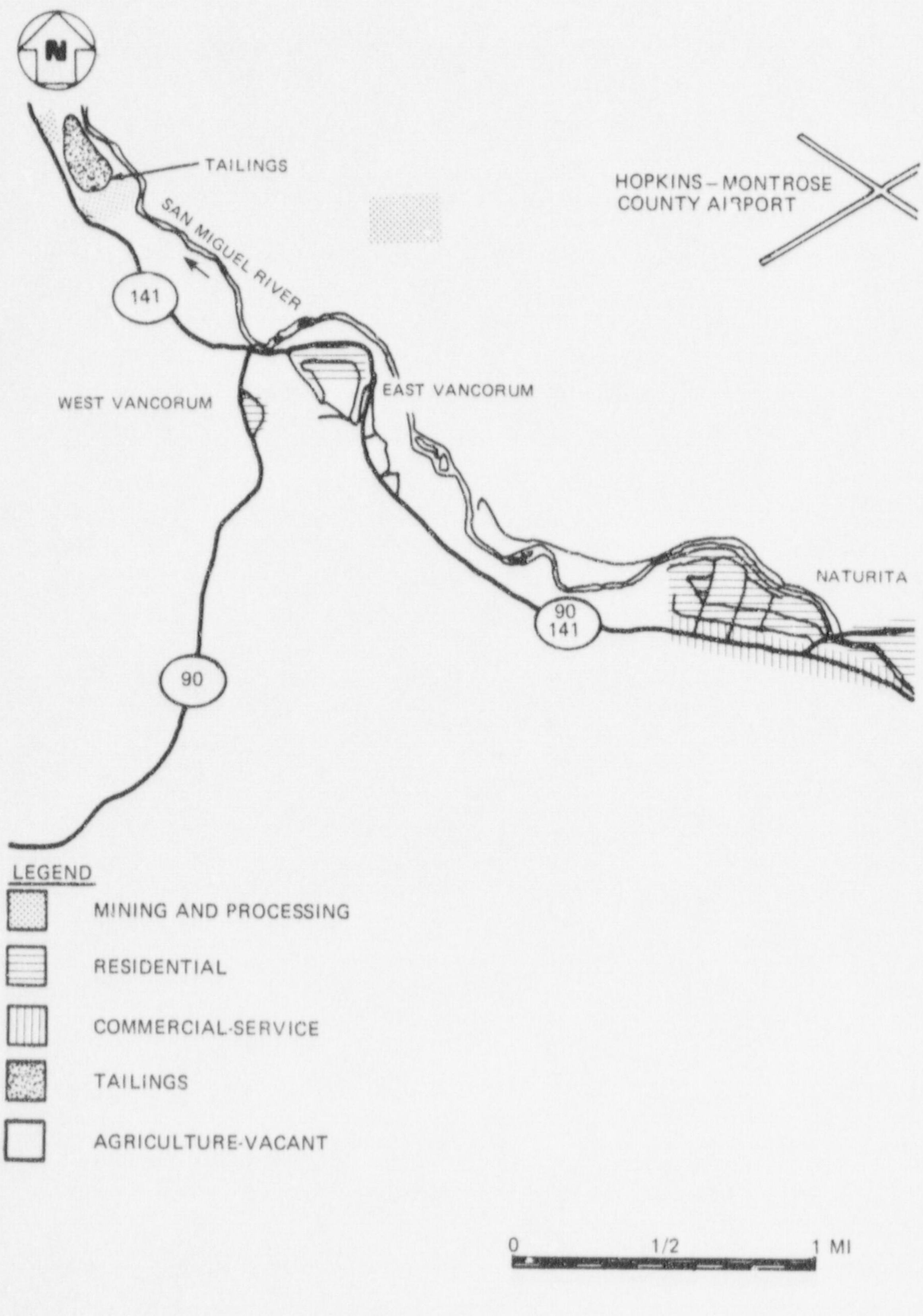

FIGURE 4-2. VICINITY LAND USE

130-07

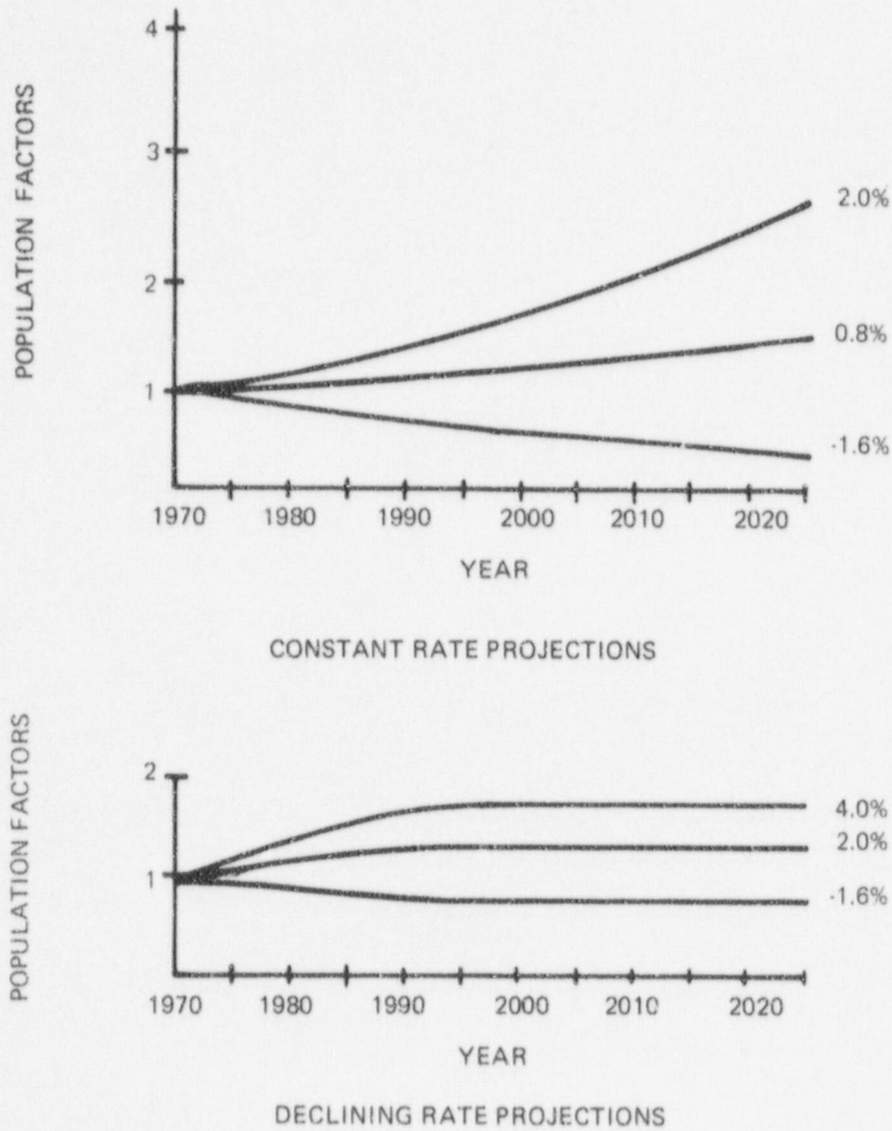

FIGURE 4-3. POPULATION PROJECTIONS

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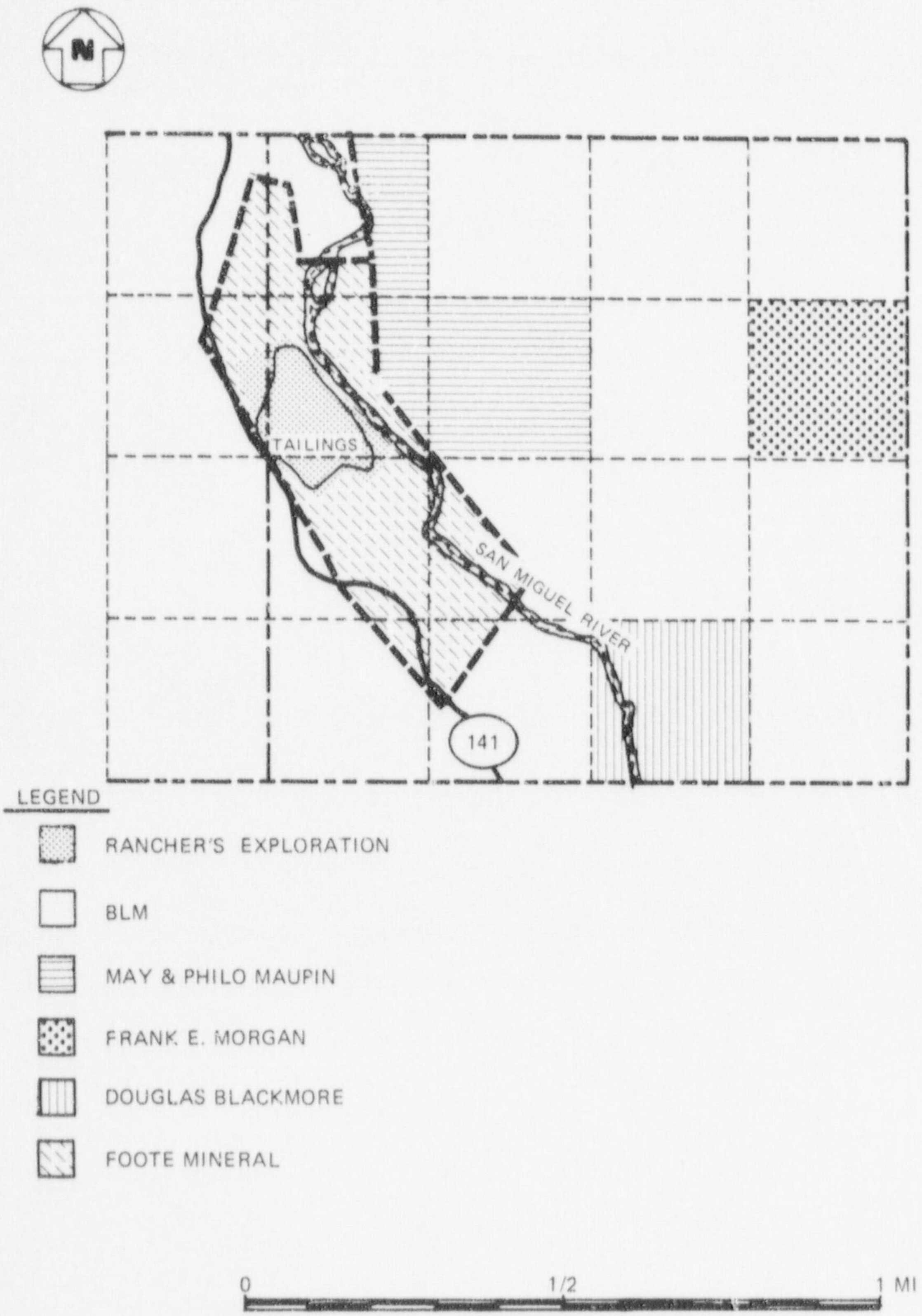

FIGURE 4-4. LAND OWNERSHIP MAP

130-07

CHAPTER 4 REFERENCES

1. J. L. England; "Baseline Data and Land Use Impact of the Naturita Uranium Tailings Site"; Center for Health and Environmental Studies, Brigham Young University, Provo, Utah; 1976.

CHAPTER 5

RECOVERY OF RESIDUAL VALUES

CHAPTER 5

RECOVERY OF RESIDUAL VALUES

Ranchers Exploration and Development Company has established the economic feasibility of reprocessing the Naturita tailings and has a license from the State of Colorado to reprocess these tailings. Ranchers estimates that the cost based upon the percentage recovery will range from \$30 to \$34/lb of U_3O_8. This range is consistent with estimates resulting from the techniques used for other sites in the Phase II program. The site to be used for the heap leach operation is illustrated in Figure 5-1.

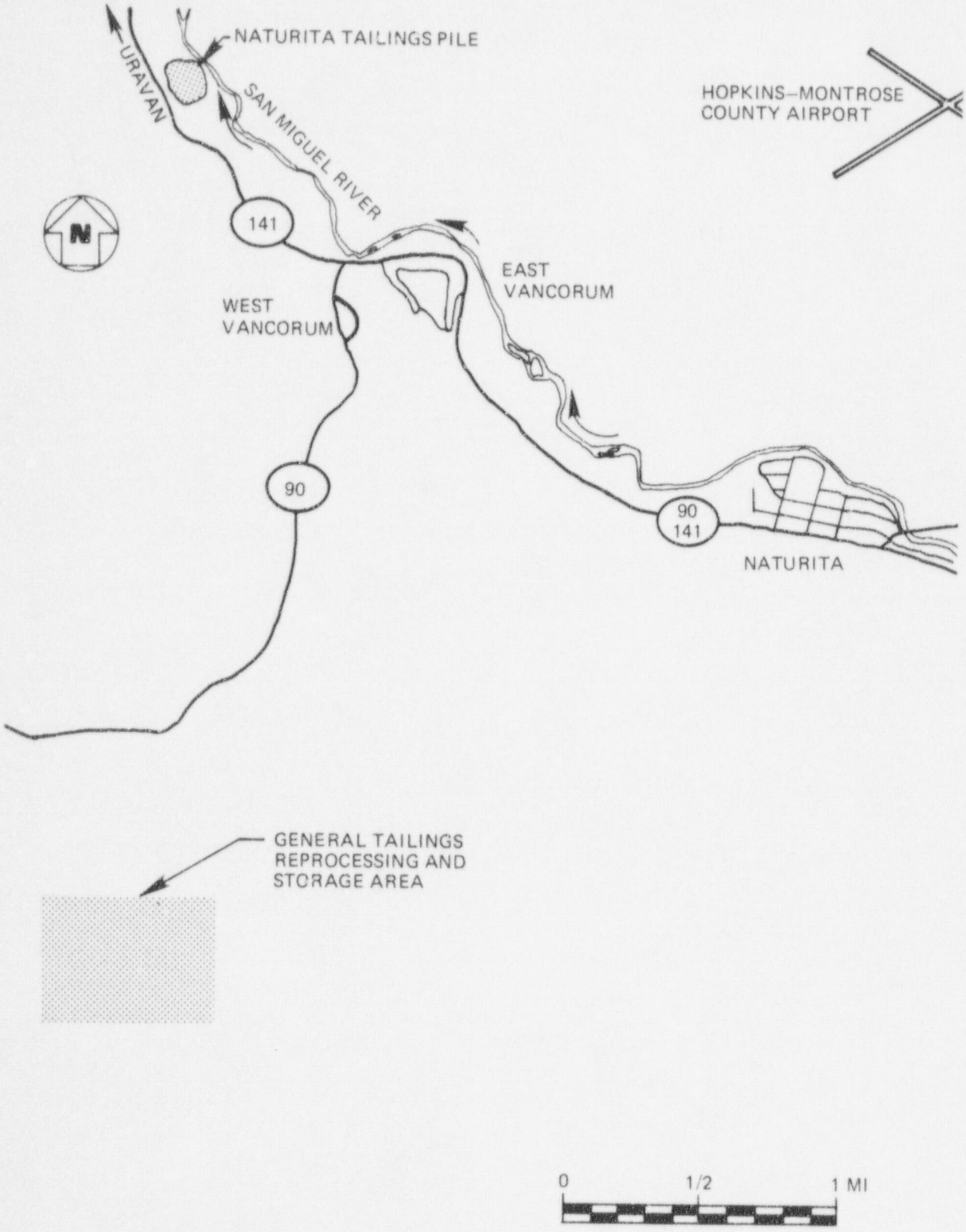

FIGURE 5-1. LOCATION OF PROPOSED REPROCESSING AND STORAGE SITE

130-07

CHAPTER 6

MILL TAILINGS STABILIZATION

CHAPTER 6

MILL TAILINGS STABILIZATION

In most of the alternative remedial actions which have been considered, the stabilization of mill tailings is a required process. Government agencies and private industry have carried out limited research to develop economical and environmentally suitable methods of uranium tailings site stabilization. All present methods, technology, and research data on stabilization that are available were reviewed to determine the best approach. In addition, experiments are being conducted to determine the relative effectiveness of various stabilization techniques.

The objective of stabilizing the uranium mill tailings is to eliminate the pathways to the environment of the radioactive and other toxic particles as described previously in Chapter 3. Ideally, complete stabilization of radioactive tailings should permanently eliminate the possibilities of:

(a) Wind and water erosion

(b) Leaching of radioactive materials and other chemicals

(c) Radon exhalation from the tailings

(d) Gamma radiation emitted from the tailings

6.1 PREVENTION OF WIND AND WATER EROSION

Wind and water erosion can be prevented by chemical stabilization of the surface, complete chemical stabilization, physical stabilization, and vegetative stabilization.

6.1.1 Chemical Stabilization of the Surface

This process involves applying chemicals to the surface of the tailings to form a water- and wind-resistant crust. Chemical stabilizers have been used successfully as a temporary protection on portions of dikes and tailings ponds which have dried and become dusty, and in areas where water shortage or chemical imbalance in the tailings prevents the use of cover vegetation. Chemical surface stabilizers, however, are susceptible to physical breakup and gradual degradation and will meet the long-term requirements for the Naturita tailings pile.

Other complications also can arise in achieving satisfactory chemical stabilization in that the surfaces of tailings piles seldom are homogeneous, and variables such as particle size and moisture content affect the bonding characteristics of the chemical stabilizers.[1]

Tests were conducted by the Bureau of Mines[1] using certain chemicals (e.g. Compound SP-400 Soil Gard, and DCA-70 elastomeric polymers) on both acidic and alkaline uranium tailings. Subsequently, the chemicals DCA-70 and calcium lignolsulfonate were applied to the surfaces of the inactive uranium tailings ponds and dikes at Tuba City, Arizona, in May 1968, because low moisture conditions and high costs prohibited vegetative or physical stabilization. After 4 yr, approximately 40% of the dike surface showed disruption while the crust in pond areas was affected to a lesser extent. The major disruptions were attributed to initial penetration of the stabilizer by physical means such as vehicles, people, or animals crossing the tailings surface.

In 1969, a portion of the Vitro tailings at Salt Lake City, Utah was sprayed with tarlike material as a Bureau of Mines experiment to achieve surface stabilization and to reduce wind erosion. The attempt was unsuccessful because the material decomposed and the tailings were exposed within 2 to 3 yr. Thus, no chemical sealant has been used successfully to stabilize uranium tailings for more than a few years.

6.1.2 Complete Chemical Stabilization

This process, which has been used in other mineral industry operations, involves the addition of chemicals in sufficient quantities to a slurry to produce a chemical reaction which solidifies the slurry. Chemicals may be added in two ways: to a slurry pipeline, and in situ. The in situ method of stabilization is relatively new, and extensive research is required in each individual situation to define the optimum chemical addition to produce the desired results.

One of the features claimed for this stabilization method is that all pollutant chemicals are locked in the solidified slurry and chemicals cannot be leached from the solid.

The cost of this stabilization method is expensive for the chemicals alone. A cover material, such as gravel, would be required to protect the solidified slurry from wind and water erosion. It is not known whether vegetation can be established after topsoil and other soil cover have been spread over the solidifies slurry. This probably would be a function of the specific chemical makeup of the solidified slurry and would require research to identify the conditions under which vegetation could thrive.

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[1] See end of chapter for references.

6.1.3 Physical Stabilization

Physical stabilization consists of isolating the contained material from wind and water erosion by covering the tailings with some type of resistant material (e.g. rock, soil, smelter slag, broken concrete, asphalt, etc.) Thin covers of concrete or asphaltic materials have been shown to break down over relatively short periods of time; and starting within a few years after application, continuing maintenance is required. A concrete covering sufficiently thick and properly reinforced would be relatively permanent and maintenance-free, but the cost would be prohibitive for large areas.

In some arid regions, where the potential for successful vegetative stabilization is slight, physical stabilization may be the preferred alternative. In such areas, combinations of pit-run sand and gravel, soil, and riprap have been placed over the tailings and have been successful in preventing wind and water erosion. An important component of physical stabilization is the proper treatment of the finished surface by such means as contour-grading and terracing. Such treatments can reduce greatly long-term maintenance costs.

6.1.4 Vegetative Stabilization

This method involves the establishment of vegetative cover on the tailings or on a growing medium placed over the tailings.

Many species of plants are self-regenerating and require little or no maintenance after growth becomes established. Vegetation can survive providing that:

(a) Evapotranspiration is not excessive

(b) Landscapes are properly shaped

(c) Nontoxic soil mediums capable of holding moisture are provided

(d) Irrigation and fertilization appropriate to the area are applied

(e) Proper selection of plants conducive to self-regeneration under conditions anticipated over a long time.

Growth of vegetation at sites receiving less than 10 in. of annual precipitation and with high evapotranspiration rates requires irrigation and fertilization. At Naturita rainfall averages about 11 in. annually.

The Naturita mill was shut down in 1963, and in 1969-70 the top surface of the pile was contoured with a minimum of 6-in. of soil, fertilized, seeded, and a sprinkler system installed. The pile was sprinkled for 1 yr until the root system of the planted grasses was established. The grasses are now being sustained by precipitation.

One potential problem in the use of vegetative stabilization is the possibility of pickup of radioactive elements by the plants. The effect of this mechanism has not been considered in the present assessment.

In 1973 and 1976, unusually heavy rainstorms eroded a portion of the cover material and tailings. Tailings were deposited on the cover material on the southwest portion of the pile. The berm dike along the north ridge of the pile was damaged causing the north slope of the pile to erode and wash out the foot dike in several localized areas.

6.2 PREVENTION OF LEACHING

Leaching into underground aquifers is one of the several pathways that chemicals and radioactive materials might take into the environment. The techniques which could be employed to control leaching include the following:

(a) Employ chemical stabilization to prevent leaching into underground aquifers (this is the same stabilization system discussed in paragraph 6.1.2).

(b) Physically compact the tailings to reduce the percolation of water through the materials.

(c) Contour the tailings surface, then employ appropriate chamicals (discussed in paragraph 6.1.1) to seal the surface, thus preventing water from penetrating and destabilizing the tailings.

(c) For a new site, line the storage area with an impermeable membrane (Bentonitic clays and various plastic materials commonly are used for this purpose).

6.3 REDUCTION OF RADON EXHALATION

Little research has been directed toward reduction of radon exhalation from tailings piles. While there are materials that can seal or contain the gas in small quantities, none of these are suitable for permanent coverage of large areas.

From simplified diffusion theory estimates, about 13 ft of dry soil[2,3] are needed to reduce radon flux by 95%, but only a few feet of soil are needed if a high moisture content in the cover material is maintained. Figure 6-1 illustrates curves of the reduction of radon exhalation flux for three soil types versus depth of cover based upon the theory and diffusion coefficients presented in the above references. Research is under way to explore more precisely the problems associated with reducing and eliminating the exhalation of radon from radioactive tailings material. The effects of applying various chemical stabilizers and varying thicknesses of stabilizing earth covers and combinations of materials are still being investigated. The results may have an important impact in planning radon exhalation control.

6.4 REDUCTION OF GAMMA RADIATION

A few feet of cover material are sufficient to reduce gamma radiation to acceptable levels.

The reduction of gamma exposure rates resulting from a packed earth covering is given in Figure 6-2.[4.5] Two feet of cover reduces the gamma levels by about two orders of magnitude. Therefore, an average cover of 2 ft should reduce gamma levels to less than 10 μR/hr above background.

6.5 ASSESSMENT OF APPLICABILITY

Available data indicate that none of the methods used thus far to stabilize uranium tailings sites has been a totally satisfactory solution to uranium tailings site radiation problems. Some of the methods examined have exhibited short-term advantages, but no economical long-term solutions have become apparent. Consequently, new methods of stabilization may have to be developed and additional engineering research may be required.

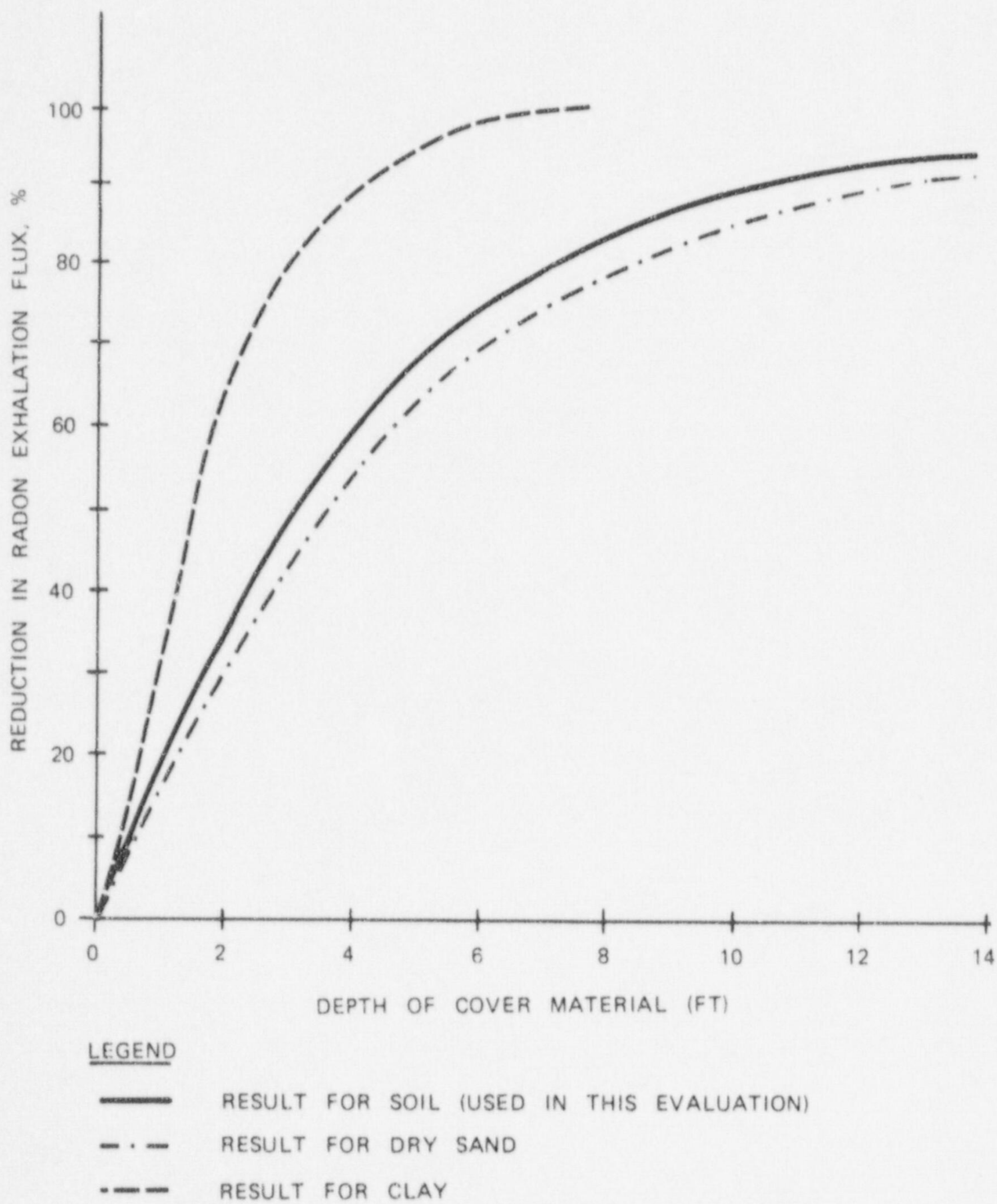

FIGURE 6-1. REDUCTION OF RADON EXHALATION FLUX WITH DEPTH OF COVER

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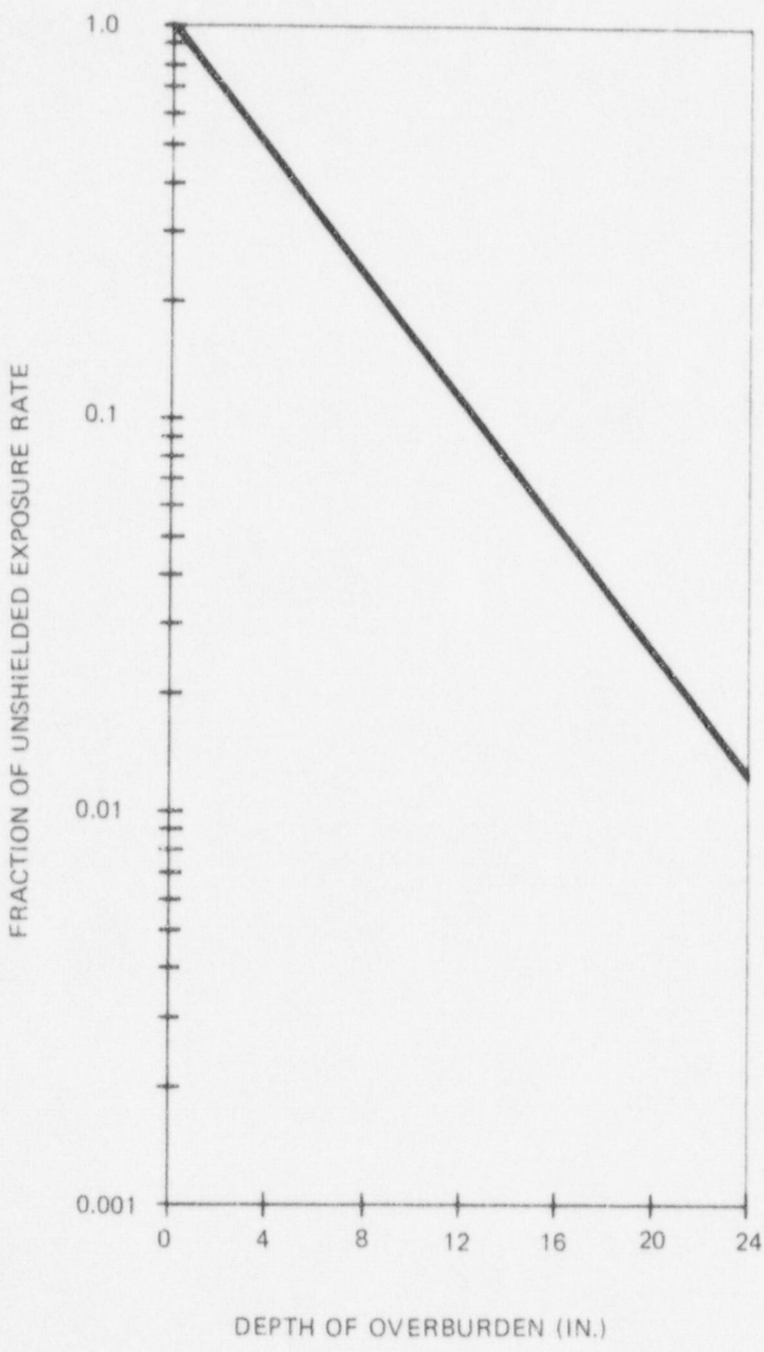

FIGURE 6-2 REDUCTION OF GAMMA EXPOSURE RATE RESULTING FROM PACKED EARTH SHIELDING

130-07

CHAPTER 6 REFERENCES

1. "Methods and Costs for Stabilizing Fine Sized Mineral Wastes"; Bureau of Mines Report of Investigation, RI7896; 1974.

2. A. B. Tanner; "Radon Migration in the Ground: A Review"; The Natural Radiation Environment; J. A. S. Adams and W. M. Lowder, eds; University of Chicago Press; 1964.

3. H. W. Kraner, G. L. Schroeder, and R. D. Evans; "Measurements of the Effects of Atmospheric Variables of Radon-222 Flux and Soil-Gas Concentrations"; The Natural Radiation Environment; J. A. S. Adams and W. M. Lowder, eds; University of Chicago Press; 1964.

4. K. J. Schiager; "Analysis of Radiation Exposures on or Near Uranium Mill Tailings Piles"; Radiation Data and Reports; Vol 15; 1974.

5. "Evaluation of Various Methods, Techniques and Materials for Stabilizing Uranium Mill Tailings"; FB&DU Report (in preparation).

CHAPTER 7

REMEDIAL ACTIONS AND BENEFITS

CHAPTER 7

REMEDIAL ACTIONS AND BENEFITS

The remedial actions for the Naturita site take into consideration the reprocessing and reclamation program proposed by Ranchers Exploration and Development Company in its license application. Assuming that program is performed, then the tailings will be relocated, reprocessed, and stabilized in the location shown in Figure 5-1, Chapter 5. In addition, the contaminated soil beneath the tailings will be moved to the same location and will be stabilized. The ^{226}Ra concentration in the subsoil beneath the pile is given in Figure 7-1. As shown in the figure, the ^{222}Ra concentration reaches twice background at a depth of about 5 ft. Also given in Figure 7-1 is the estimated cost per foot to remove the contaminated subsoil.

The remedial action options that should be considered in addition to the above program are directed towards the remedial action at off-site structures and off-pile windblown tailings.

7.1 DATA SOURCES

A mobile scanning unit, operated by the AEC under an interagency agreement with EPA, performed gamma radiation surveys of the Naturita and Nucla, Colorado areas in 1971. Of the 219 structures scanned in Naturita, 33 anomalies were reported while at Nucla, 13 anomalies resulted from the survey of 265 structures. A joint team from the EPA Office of Radiation Programs, Las Vegas, Nevada (EPA-ORP-LV) and the Colorado Department of Health performed individual gamma surveys of the 46 anomalies to determine their sources and, if tailings, how they had been used.[1,2] High and low inside and outside gamma readings were recorded. A gamma map was drawn of gamma readings inside the structures exceeded 20 μR/hr.

The EPA gamma survey[3] for windblown tailings was the data source used for consideration of the remedial action for open land areas.

7.2 REMEDIAL ACTION FOR STRUCTURES (OPTION I)

Follow-up surveys of the anomalies[1,2] indicated that there were 10 tailings use locations in Naturita and 3 in Nucla. In Naturita, the tailings uses ranged from use in foundations to fill under walkways and slabs and included such miscellaneous uses as planter fill, contaminated fire brick use, and contamination resulting from incineration of contaminated trash. In Nucla, the tailings were used under building floor slabs and as fill in a driveway. Radon measurements were performed at two locations in

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[1] See end of chapter for references.

Nucla at the request of the Colorado Department of Health. (See Figure 3-3, Chapter 3.)

Of the remaining 33 anomalies identified by the 1971 scanning survey, 26 were caused by the presence of radioactive material in instruments or ore, 3 resulted from natural radioactive materials, and 4 could not be verified as anomalies.

An extended series of measurements, such as required in the full application of the Grand Junction remedial action criteria, might modify the actual number of locations included in the remedial action. The location at which tailings are on vacant lands or are greater than 10 ft from structures could constitute a problem in the future. Costs for this category are not included in this assessment because they are not covered under the Grand Junction remedial action criteria.

Remedial action would remove tailings and contaminated material from locations meeting the remedial action criteria and restore the disturbed locations to their original condition. In addition, mill structures would be either decontaminated or demolished and buried, depending upon the condition of the structures and the cost of decontamination versus demolition.

7.2.1 Costs

As shown in Table 7-1, the cost for this option is $270,000. The major cost components are as follows:

(a)	Engineering (15% of item b)	$ 26,000
(b)	Remedial action	170,000
(c)	Environmental assessment	40,000
(d)	Contingency (15% of items a, b and c)	34,000
	Total Cost	$270,000

7.3 REMEDIAL ACTION FOR OPEN LANDS (OPTION II)

In addition to the actions proposed in Option I, this option includes cleanup of some of the windblown tailings. The extent of windblown tailings is indicated by the EPA data[3] in Figure 3-10, Chapter 3. Decontamination of windblown tailings consists of removing the off-pile contaminated soil and transporting it to the reprocessing site. The area which will be decontaminated is shown in Figure 7-2. The presently operating ore buying station (on the millsite) and former ore storage area have not been included in this area. Most areas would be decontaminated by removing an average of 8 in. of soil, except for the area to the southeast of the tailings where an average of 3 ft of soil would be removed. After decontamination, the affected areas would be restored with additional clean material and vegetation would be reestablished. All structures would be decontaminated by either wet or dry vacuum procedures.

7.3.1 Costs

As shown in Table 7-1, the cost for this option is $950,000. The major cost components are as follows:

(a)	Engineering (10% of item b)	$ 70,000
(b)	Remedial action	700,000
(c)	Environmental assessment	60,000
(d)	Contingency (15% of items a, b, and c)	120,000
	Total Cost	$950,000

The costs for moving the tailings and contaminated subsoil to another location 5 mi away, including site preparation, 2 ft of cover on the tailings after placement, fencing, and an endowment fund for annual maintenance, are $4,500,000.

7.4 IMPACTS OF THE OPTIONS

7.4.1 Health Benefits

Although the Ranchers Exploration program and the present options would leave the tailings site in a condition suitable for unrestricted use, the presence of the stockpiled ore and the ore buying station necessitate restricted activities at this site.

As discussed in Chapter 3, the health effects from the pile are negligible and will be reduced further by the Ranchers Exploration program. In view of the small health effects, no cost-benefit analysis has been performed for this site; however, in general the remedial action on structures (Option I) has a very favorable health benefit-to-cost ratio.

7.4.2 Land Value Benefits

A good portion of the property surrounding the Naturita site is under management of the Bureau of Land Management. There are three private land owners adjacent to the site. The estimated market value of the land (excluding improvements or mineral values) varies from less than $50/acre to almost $1,200/acre; hence, after removal of the tailings, the value of the approximately 24 acres of land covered by tailings could increase from a current estimated $200/acre to a possible $1,000/acre for a net increase of $19,200.

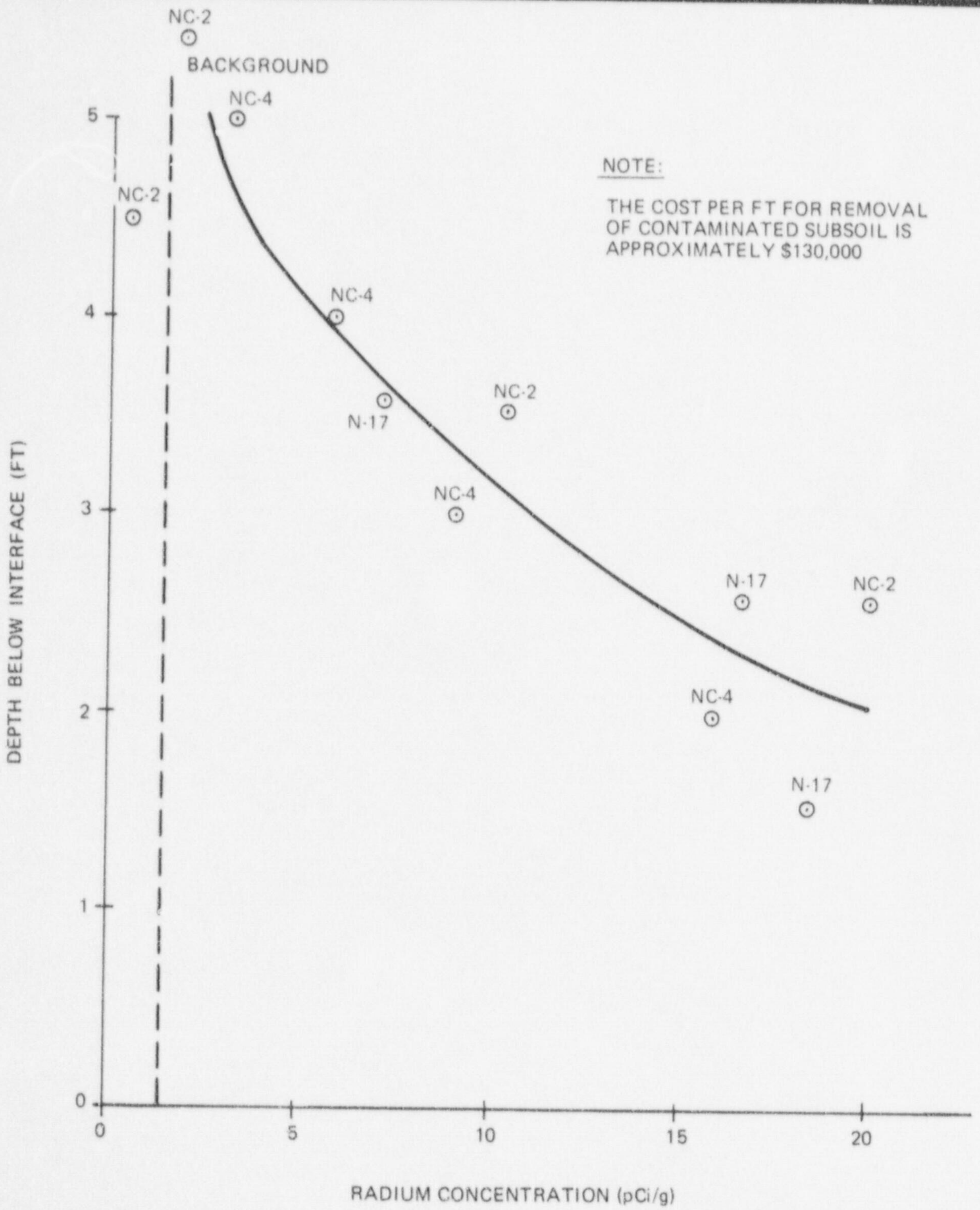

FIGURE 7-1. RADIUM ACTIVITY CONCENTRATION IN CONTAMINATED SUBSOIL

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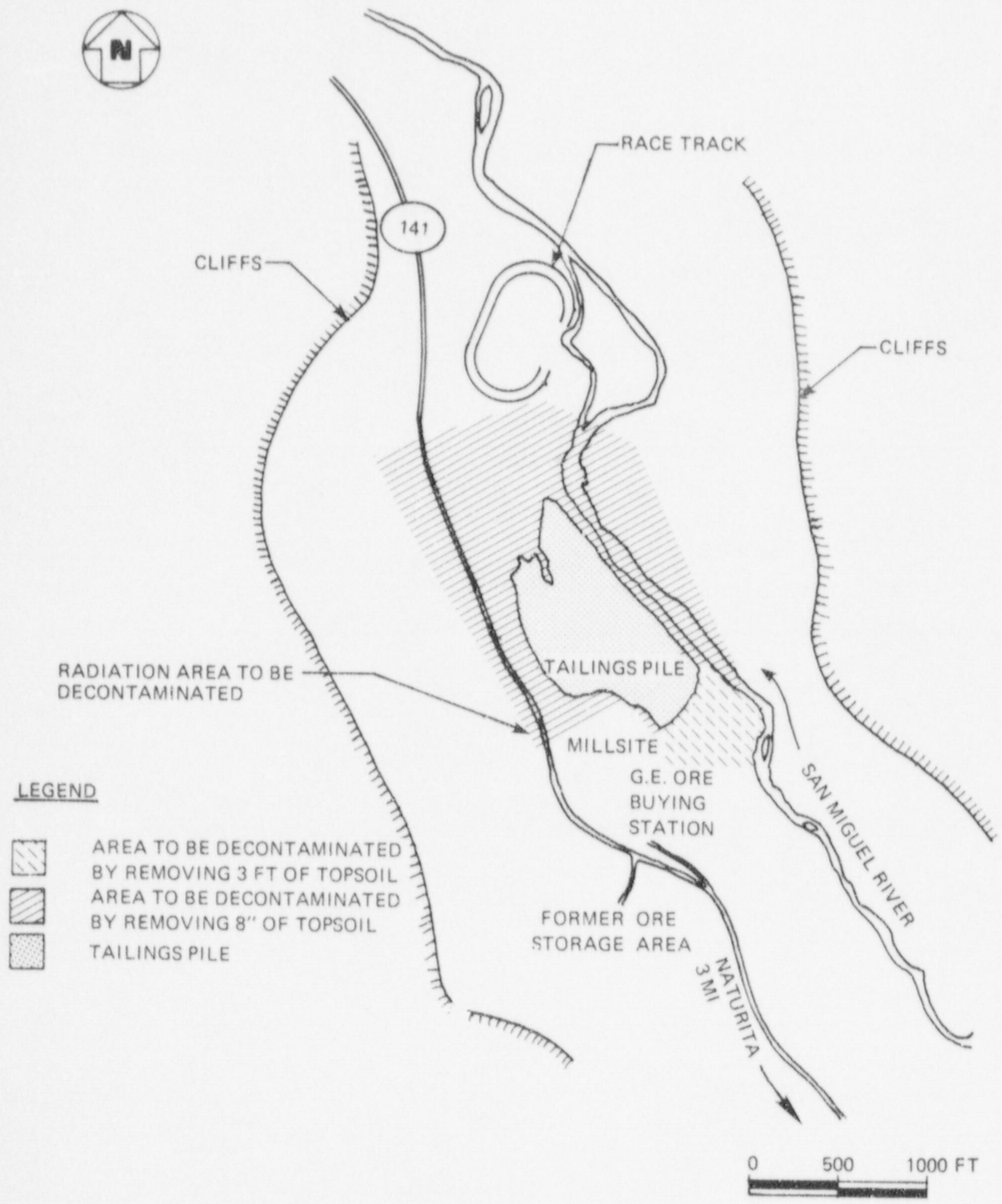

FIGURE 7-2. AREA DECONTAMINATION PLAN

130-07

TABLE 7-1

COST ESTIMATE SUMMARY

Option No.	Description	Estimated Cost ($)*
I	Decontamination at off-site structures and mill-site structures.	$270
II	Cleanup of windblown tailings adjacent to the site, and of other contaminated soils at the site, in addition to the work of Option I.	$950

*Costs are in thousands of dollars, based on 1977 value.

CHAPTER 7 REFERENCES

1. "Summary Report of the Radiation Surveys Performed in the State of Colorado at Naturita, Colorado"; EPA-ORP-LV; Mar 1973.

2. "Summary Report of the Radiation Surveys Performed in the State of Colorado at Nucla, Colorado"; EPA-ORP-LV; Mar 1973.

3. R. L. Douglas and J. M. Hans, Jr.; "Gamma Radiation Surveys at Inactive Uranium Mill Sites"; Technical Note ORP/LV-75-5; EPA; Office of Radiation Programs; Las Vegas, Nevada; Aug 1975.

APPENDIX A

REMEDIAL ACTION CRITERIA

A.1 Surgeon General's Guidelines

A.2 Radiological Criteria for Decontamination of Inactive Uranium Mill Sites

A.3 Grand Junction Remedial Action Criteria (10CFR712)

APPENDIX A

REMEDIAL ACTION CRITERIA

The remedial action criteria used for the Phase II assessment of the cleanup of mill tailings are presented in the following documents:

A.1 SURGEON GENERAL'S GUIDELINES

DEPARTMENT OF HEALTH, EDUCATION AND WELFARE,
PUBLIC HEALTH SERVICE,
Washington, D. C., July 1970.

DR. R. L. CLEERE,
Executive Director, Colorado State Department of Health, 4210 E. 11th Avenue, Denver, Colorado

DEAR DR. CLEERE: I am pleased to respond to your letter of January 29 in which you asked Dr. M. W. Carter, Director of our Southwestern Radiological Health Laboratory, for Public Health Service and/or U. S. Atomic Energy Commission assistance in providing exposure guidelines applicable to homes with high concentrations of radon progeny.

The enclosed graded recommendations for action have been developed within the framework of existing Federal Radiation Council guidance for occupational exposure to airborne concentrations of radon and its daughters (progeny). Also, graded action levels applicable to external gamma radiation are included.

You will note in the accompanying Explanatory Notes that these recommendations apply specifically to dwellings constructed with or on uranium mill tailings. Further qualifications in the Explanatory Notes should be consulted before these recommendations are applied.

The specific information which your Department is developing on the variability of radon daughter concentrations in dwellings and on optimum control measures will be essential towards making those decisions necessary in applying the recommendations.

These recommendations have been directed to the Atomic Energy Commission for comment. Because of the urgency attached to your receiving the recommendations as soon as possible, they have been forwarded to you in advance of receiving AEC views and comments. We will advise you of the AEC response when received.

Sincerely yours,

PAUL J. PETERSON,
Acting Surgeon General

Enclosure:

RECOMMENDATIONS OF ACTION FOR RADIATION EXPOSURE LEVELS IN DWELLINGS CONSTRUCTED ON OR WITH URANIUM MILL TAILINGS

External gamma radiation:

Level:	Recommendations
Greater than 0.1 mR/hr . . .	Remedial action indicated.
From 0.05 to 0.1 mR/hr . . .	Remedial action may be suggested.
Less than 0.05 mR/hr . .	No action indicated.

Level:	Recommendations
Greater than 0.05 WL	Remedial action indicated.
From 0.01 to 0.05 WL	Remedial action may be suggested.
Less than 0.01 WL	No action indicated.

EXPLANATORY NOTES

1. These recommendations are written specifically for dwellings constructed on or with uranium mill tailings. This situation may involve continuous exposure of members of the public to radon daughter product activities and whole-body gamma irradiation levels in excess of the background radiation levels found within dwellings in the area not constructed with or on uranium mill tailings.

2. Although the initial concern was the presence of radon daughter product activities within these dwellings, preliminary surveys have indicated that in some instances, the gamma radiation levels were of prime importance. Thus, recommendations are made concerning both types of radiation. The recommendations applicable to a particular dwelling will be determined by whichever type of radiation has the high level.

3. Three levels for action are recommended for both external gamma and radon daughter product exposures. This graded system of actions is proposed to allow latitude in the middle ranges for the judgment of the on-site investigators.

4. The external gamma and radon daughter product levels proposed constitute exposures which are in addition to the natural background levels found within dwellings in the area not constructed on or with uranium mill tailings. In the Grand Junction, Colorado, area these levels are approximately 0.01 mR/hr (approximately 90 mrem/yr) and 0.004 Working Levels (WL) (approximately 0.2 CWLM/yr) respectively (1).

5. The expected health effects of concern will be different for the two types of radiation; i.e., leukemia for whole-body gamma radiation exposure and lung cancer for exposure to inhaled radon daughter products. This expectation is based, in part, on findings derived from population studies such as the Japanese atomic bomb

survivors and uranium miners. These specific health effects are considered to be mutually exclusive. The basis for this assumption is that the expected radiation contribution to whole-body exposure from inhaled radon and daughter products would be considerably less than the direct exposure from external gamma radiation at the levels encountered in the dwellings. Conversely, the external gamma radiation contribution to the lung dose is considered to comprise a negligible additional risk of lung cancer.

6. (a) A Working Level (WL) is the term used to describe radon daughter product activities in air. This term is defined as any combination of short-lived radon daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy (2). The numerical value of the WL is derived from the alpha energy released by the total decay through Ra C' of the short-lived radon daughter products, Ra A, Ra B and Ra C, at radioactive equilibrium with 100 pCi of ^{222}Rn per liter of air (3).

6. (b) A Working Level Month (WLM) is the term used to express the occupational exposure incurred in one working month of 170 hours by a uranium miner laboring in an atmosphere containing radon daughter products; i.e., one working month in a mine atmosphere containing 1 WL of radon daughter products equals 1 WLM.

6. (c) Cumulative Working Level Months (CWLM) is the term used to express the total accumulated occupational exposure to radon daughter products in air; i.e., an air concentration of radon daughter products of 1 WL would, in one working month, equal 1 WLM, and in 1 year or 12 months would equal 12 CWLM.

6. (d) Since occupational exposures are based upon 170 hours per month and continuous exposure involves approximately 170 hours per week, then an occupational exposure to an air concentration of 1 WL is equivalent to continuous exposure to 0.025 WL.

7. These recommendations are based on the assumption of a linear, non-threshold dose-effect relationship. The lack of definitive information precludes allowances for possible differences in radio-sensitivity due to age, sex, or other biological characteristics.

8. No action is indicated when the external gamma exposure rate is less than 0.05 mR/hr and the radon daughter product activity is less than 0.01 WL since under conditions of continuous exposure these levels would result in maximum annual exposures of approximately 400 mrem and 0.5 CWLM, respectively. The maximum annual value of 400 mrem is less than the dose limits recommended for an individual body exposure to external gamma irradiation.

The ICRP (5) recommends that the annual dose limit for members of the public shall be 1/10 of the corresponding annual occupational maximum permissible dose. The maximum annual value of 0.5 CWLM of radon daughter product exposure is approximately 1/10 of the 4 CWLM annual occupational exposure limit recommended by the FRC (6) for implementation on 1 January 1971, and less than 1/20 of the annual occupational exposure limit of 12 CWLM recommended for uranium miners in the present FRC regulations (4).

9. Remedial action may be suggested in the case of external gamma exposure rates of 0.05-0.10 mR/hr or radon daughter product activities of 0.01-0.05 WL since under conditions of continuous exposure these levels would result in maximum annual exposures of approximately 400-900 mrem and 0.5-2.5 CWLM. The upper limit of these ranges exceeds the strictly applied recommendations of the FRC and ICRP for exposures of an individual member of the public. However, this extension seems justified in situations in which unforeseen exposures have occured, since as stated by ICRP (5) "in general it will be appropriate to institute countermeasures only when their social cost and risk will be less than those resulting from the exposure." It is further stated by the ICRP (5) that very low levels of risk are implied in the dose limits for members of the public and that it is likely to be of minor consequence to their health if the dose limits are marginally or even substantially exceeded.

10. Remedial action is indicated at gamma exposures greater than 0.1 mR/hr or at radon daughter product activities greater than 0.05 WL. Under conditions of continuous exposure, these levels would result in minimum annual exposures of 900 mrem and 2.5 CWLM. All values above these would indicate the necessity for remedial action, since at these levels the maximum annual exposures recommended by the FPC and ICRP for an individual member of the public is exceeded.

11. With respect to the external gamma irradiation, from the estimates published by ICRP (7), it can be interpolated that the annual risk of leukemia under conditions of continuous exposure to 500 mrem per year is an increased incidence of about 10 cases per year per million persons exposed. The natural annual incidence of leukemia for all ages is given by ICRP (8) as 10-100 cases per million persons. With respect to radon daughter product exposures, it has been estimated by Archer and Lundin (9) that an exposure of 120 CWLM to a group of white adult males in the United States appears to approximately double the normal lung cancer incidence which for this population is about 2-3 cases per year per 10,000 persons. At an annual exposure of 2.5 CWLM, 48 years would be required to reach 120 CWLM.

12. It is considered that implementation of these recommendations for the various exposure ranges would make it highly unlikely that any serious health effects would result from exposure to radon daughter products or external gamma irradiation in this particular situation.

13. It is suggested that remedial action be taken only after an adequate number of measurements taken under a diversity of temporal and climatic conditions have clearly established that the average exposure is in excess of 0.1 mR/hr or 0.05 WL exist and in instituting corrective measures. However, it is considered that the additional health risks from continued exposure over this time period are of lesser consequence than the economic and social discomfitures of precipitous action.

Approved.

/s/ PAUL J. PETERSON,
for Jesse L. Steinfeld, M.D.,
Surgeon General, Public Health Service

July 27, 1970

REFERENCES

1. Personal communication, Mr. Robert D. Siek, Colorado State Department of Health.

2. U.S. Public Health Service Publication No. 494, Control of Radon and Daughters in Uranium Mines and Calculations on Biologic Effects, 1957.

3. Federal Radiation Council Report No. 8 Revised, Guidance for the Control of Radiation Hazards in Uranium Mining, 1967.

4. Federal Radiation Council Report No. 1. Background Material for the Development of Radiation Protection Standards, 1960.

5. Recommendations of the International Commission on Radiological Protection, ICRP Publication 9, 1966.

6. Federal Register, Vol. 34, No. 10, pp 576-577, 1969.

7. The Evaluation of Risks from Radiation, ICRP Publication 8, 1966.

8. Radiosensitivity and Spatial Distribution of Dose, ICRP Publication 14, 1969.

9. V.E. Archer and F. E. Lundin, Jr., Radiogenic Lung Cancer in Man: Exposure-Effect Relationship, Environmental Research 1, pp 370-383, 1967.

A.2 RADIOLOGICAL CRITERIA FOR DECONTAMINATION OF INACTIVE URANIUM MILL SITES*

1. General

Radiological criteria for an engineering assessment of possible remedial actions applicable to uranium mill tailings piles and for the decontamination of inactive uranium mill sites are provided herein. These criteria are applicable to the sites, to their surrounding areas which have been contaminated by radioactive materials from the sites, and to buildings in which the materials have been used.

Critical radiation exposure pathways from inactive uranium mill sites to members of the general population are:

(a) Radon escaping from the tailings pile carried by the wind into habitable structures where the holdup time is long enough, resulting in buildup of radon daughters to levels greater than the ambient air.

(b) Tailings material used for construction of habitable structures can result in a buildup of radon daughters and increased gamma levels.

(c) Gamma rays from tailings material cause whole body radiation exposure. This includes not only the "gamma shine" from the tailings pile that exposes people living nearby, but also the radiation exposure from tailings material that has been eroded off the pile onto surrounding land. The mill sites always show elevated gamma exposure levels because of contamination by ore, tailings solids, and process solutions.

(d) ^{226}Ra, Th, and other radionuclides from tailings piles can be leached into ground water and thereafter into public and irrigation water supplies.

(e) Windblown particulate material (Ra and Th) from the tailings pile can be inhaled causing a radiation dose to the lung.

Remedial actions may be required on inactive uranium mill tailings piles to reduce or prevent excess radiation exposure from radon progeny, gamma radiation, ^{226}Ra, and radioactive particulate material. If tailing material has been used as a building material, remedial actions may be required to reduce radon concentrations and/or gamma activity levels. Remedial actions performed on tailings piles

*Provided by U S Environmental Protection Agency, as attachment to letter dated Dec 1974.

and decontamination of mill sites and surrounding contaminated areas should result in residual exposures that are as low as practicable. There is no single permissible exposure level applicable to all such cases. An evaluation should be made on a case-by-case basis of the risk involved, balanced against (1) the cost of reducing the residual contamination, and (2) the economic effect on alternatives such as restricting the use of the land. The result of such an analysis can be used by all concerned to define the "as low as practicable" residual level of contamination that will be acceptable and determine whether restrictions will be required on the use of any contaminated land.

2. Tailings Pile or Pond

The operation of uranium mills results in the generation of waste material which is disposed of in tailings piles and ponds. Environmental contamination has occurred at those sites where measures were not taken to control the movement of the radioactive material. In order to restore the environmental quality and provide for protection of the public, such sites should be decontaminated and result in residual gamma radiation levels which are as low as practicable. For most situations this would require decontamination of the area by (1) removal of radioactive material to a location where the material would be isolated from the biosphere, or (2) providing sufficient cover such that the resultant gamma radiation levels are as low as practicable, preferably at background. However, under certain topographical conditions and economic considerations wherein complete removal is not practicable, the residual levels should not exceed 40 μR/hr above background. This value is arbitrarily chosen for the purpose of providing an engineering estimate on cleanup of contaminated areas. It is considered to be sufficiently low that the expected exposures occurring after any remedial action at this level would not constitute a public concern. However, this should not be considered as the final criterion.* The gamma radiation level is the net, corrected measurement at 3 ft above the ground.

For each site a determination should be made of the radium concentration in the soil. Cleanup should reduce the soil concentration to less than two times the radium background specific for the area.

If the radioactive material remains in place and stabilized, the area should be designated as a controlled area. Due to the difficulty of controlling radon diffusion and the existing state-of-the-art of stabilization, the land should be restricted as to human occupancy and be properly fenced to limit access.

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*When all phase II information is complete and the health impact of remedial actions identified an overall determination of as low as practicable protection levels can be assessed appropriately. Therefore, the above numbers are subject to change.

The ^{226}Ra activity contribution from the site in ground or surface water should meet applicable state or federal standards.

3. <u>Open Land Areas</u>

This area refers to all land beyond the fence of the sites where tailings are located. As with the tailings areas, decontamination of the uranium mill site and other areas contaminated by wind- or water-eroded tailings should result in residual gamma levels which are as low as practicable. Cleanup of the area would require returning of the windblown tailings material to the site and establishing a controlled area, or moving all the material to a location that will isolate the material from the biosphere.

If the residual gamma levels are less than 10μR/hr above background, the land may be released for unrestricted use. If residual levels are equal to or greater than 10μR/hr above background at a given site a determination should be made of the radium concentration in the soil. Cleanup should reduce the soil concentration to no more than two times the radium background specific for the area. Under certain topographical conditions wherein complete removal of tailings is not possible or practicable, the residual levels should be as low as practicable but should not exceed 40μR/hr above background and access should be controlled. This value is arbitrarily chosen for the purpose of providing an engineering estimate on cleanup of contaminated areas. The gamma radiation level is the net, corrected measurement at 3 ft above the ground.

4. <u>Structures</u>

It is possible that there will be several industrial and residential structures where tailings have been utilized for construction purposes. When it has been determined that tailings were used in the construction, the lower limits of the guidelines established by the Surgeon General for structures in Grand Junction, Colorado, will be used.

PART 712—GRAND JUNCTION REMEDIAL ACTION CRITERIA

AUTHORITY: Sec. 203, 86 Stat. 226.

§ 712.1 Purpose.

(a) The regulations in this part establish the criteria for determination by ERDA of the need for, priority of and selection of appropriate remedial action to limit the exposure of individuals in the area of Grand Junction, Colo., to radiation emanating from uranium mill tailing which have been used as a construction-related material.

(b) The regulations in this part are issued pursuant to Pub. L. 92-314 (86 Stat. 222) of June 16, 1972.

§ 712.2 Scope.

The regulations in this part apply to all structures in the area of Grand Junction, Colo., under or adjacent to which uranium mill tailings have been used as a construction-related material between January 1, 1951, and June 16, 1972, inclusive.

§ 712.3 Definitions.

As used in this part:

(a) "Administrator" means the Administrator of Energy Research and Development or his duly authorized representative.

(b) "Area of Grand Junction, Colo.," means Mesa County, Colo.

(c) "Background" means radiation arising from cosmic rays and radioactive material other than uranium mill tailings.

(d) "ERDA" means the U.S. Energy Research and Development Administration or any duly authorized representative thereof.

(e) "Construction-related material" means any material used in the construction of a structure.

(f) "External gamma radiation level" means the average gamma radiation exposure rate for the habitable area of a structure as measured near floor level.

(g) "Indoor radon daughter concentration level" means that concentration of radon daughters determined by: (1) Averaging the results of 6 air samples each of at least 100 hours duration, and taken at a minimum of 4-week intervals throughout the year in a habitable area of a structure, or (2) utilizing some other procedure, approved by the Commission.

(h) "Milliroentgen (mR) means a unit equal to one-thousandth (1/1000) of a roentgen which roentgen is defined as an exposure dose of X or gamma radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign.

(i) "Radiation" means the electromagnetic energy (gamma) and the particulate radiation (alpha and beta) which emanate from the radioactive de-

cay of radium and its daughter products.

(j) "Radon daughters" means the consecutive decay products of radon-222. Generally, these include Radium A (polonium-218), Radium B (lead-214), Radium C (bismuth-214), and Radium C' (polonium-214).

(k) "Remedial action" means any action taken with a reasonable expectation of reducing the radiation exposure resulting from uranium mill tailings which have been used as construction-related material in and around structures in the area of Grand Junction, Colo.

(l) "Surgeon General's guidelines" means radiation guidelines related to uranium mill tailings prepared and released by the Office of the U.S. Surgeon General, Department of Health, Education and Welfare on July 27, 1970.

(m) "Uranium mill tailings" means tailings from a uranium milling operation involved in the Federal uranium procurement program.

(n) "Working Level" (WL) means any combination of short-lived radon daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

§ 712.4 Interpretations.

Except as specifically authorized by the Administrator in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of ERDA other than a written interpretation by the General Counsel will be recognized to be binding upon ERDA.

(b) Where ERDA approved data on indoor radon daughter concentration levels are not available:

(1) For dwellings and schoolrooms:

(i) An external gamma radiation level of 0.05 mR/hr. or greater above background.

(ii) An indoor radon daughter concentration level of 0.01 WL or greater above background (presumed).

(A) It may be presumed that if the external gamma radiation level is equal to or exceeds 0.02 mR/hr. above background, the indoor radon daughter concentration level equals or exceeds 0.01 WL above background.

(B) It should be presumed that if the external gamma radiation level is less than 0.001 mR/hr. above background, the indoor radon daughter concentration level is less than 0.01 WL above background, and no possible need for remedial action exists.

(C) If the external gamma radiation level is equal to or greater than 0.001 mR/hr. above background but is less than 0.02 mR/hr. above background, measurements will be required to ascertain the indoor radon daughter concentration level.

(2) For other structures: (i) An external gamma radiation level of 0.15 mR/hr. above background averaged on a room-by-room basis.

(ii) No presumptions shall be made on the external gamma radiation level/indoor radon daughter concentration level relationship. Decisions will be made in individual cases based upon the results of actual measurements.

§ 712.8 Determination of possible need for remedial action where criteria have not been met.

The possible need for remedial action may be determined where the criteria in § 712.7 have not been met if various other factors are present. Such factors include, but are not necessarily limited to, size of the affected area, distribution of radiation levels in the affected area, amount of tailings, age of individuals occupying affected area, occupancy time, and use of the affected area.

§ 712.5 Communications.

Except where otherwise specified in this part, all communications concerning the regulations in this part should be addressed to the Director, Division of Safety, Standards and Compliance, U.S. Energy Research and Development Administration, Washington, D.C. 20545.

§ 712.6 General radiation exposure level criteria for remedial action.

The basis for undertaking remedial action shall be the applicable guidelines published by the Surgeon General of the United States. These guidelines recommend the following graded action levels for remedial action in terms of external gamma radiation level (EGR) and indoor radon daughter concentration level (RDC) above background found within dwellings constructed on or with uranium mill tailings:

EGR	RDC	Recommendation
Greater than 0.1 mR/hr.	Greater than 0.05 WL.	Remedial action indicated.
From 0.05 to 0.1 mR/hr.	From 0.01 to 0.05 WL.	Remedial action may be suggested.
Less than 0.05 mR/hr.	Less than 0.01 WL.	No remedial action indicated.

§ 712.7 Criteria for determination of possible need for remedial action.

Once it is determined that a possible need for remedial action exists, the record owner of a structure shall be notified of that structure's eligibility for an engineering assessment to confirm the need for remedial action and to ascertain the most appropriate remedial measure, if any. A determination of possible need will be made if as a result of the presence of uranium mill tailings under or adjacent to the structure, one of the following criteria is met:

(a) Where ERDA approved data on indoor radon daughter concentration levels are available:

(1) For dwellings and schoolrooms: An indoor radon daughter concentration level of 0.01 WL or greater above background.

(2) For other structures: An indoor radon daughter concentration level of 0.03 WL or greater above background.

§ 712.9 Factors to be considered in determination of order of priority for remedial action.

In determining the order of priority for execution of remedial action, consideration shall be given, but not necessarily limited to, the following factors:

(a) Classification of structure. Dwellings and schools shall be considered first.

(b) Availability of data. Those structures for which data on indoor radon daughter concentration levels and/or external gamma radiation levels are available when the program starts and which meet the criteria in § 712.7 will be considered first.

(c) Order of application. Insofar as feasible remedial action will be taken in the order in which the application is received.

(d) Magnitude of radiation level. In general, those structures with the highest radiation levels will be given primary consideration.

(e) Geographical location of structures. A group of structures located in the same immediate geographical vicinity may be given priority consideration particularly where they involve similar remedial efforts.

(f) Availability of structures. An attempt will be made to schedule remedial action during those periods when remedial action can be taken with minimum interference.

(g) Climatic conditions. Climatic conditions or other seasonal considerations may affect the scheduling or certain remedial measures.

§ 712.10 Selection of appropriate remedial action.

(a) Tailings will be removed from those structures where the appropriately averaged external gamma radiation level is equal to or greater than 0.05 mR/hr. above background in the case of dwellings and schools and 0.15 mH/hr. above background in the case of other structures.

(b) Where the criterion in paragraph (a) of this section is not met, other remedial action techniques, including but not limited to sealants, ventilation, and shielding may be considered in addition to that of tailings removal. ERDA shall select the remedial action technique or combination of techniques, which it determines to be the most appropriate under the circumstances.

APPENDIX B

RULES AND REGULATIONS PERTAINING TO RADIATION CONTROL; THE STATE OF COLORADO

B.1 Part VIII - Regulation Requiring Stabilization of Uranium and Thorium Mill Tailings Piles

APPENDIX B

RULES AND REGULATIONS PERTAINING TO RADIATION CONTROL

B.1 PART VIII - REGULATION REQUIRING STABILIZATION OF URANIUM AND THORIUM MILL TAILING PILES (Radiation Regulation No. 2)

RH 8.1 All uranium and thorium mill tailing piles and ponds from inactive mills shall be stabilized in the following manner:

8.1.1 Ponds shall be drained and covered with materials that prevent blowing of dust. Water drained from the ponds shall be disposed of in a manner approved by the Water Pollution Control Commission.

8.1.2 Taking into consideration the types of materials at each site, piles shall be leveled and graded so that there is, insofar as possible, a gradual slope to ensure that there shall be no low places on the pile where water might collect. Side slopes shall be stabilized by riprap, dikes, reduction of grades, vegetation, or any other method or combination of methods that will ensure stabilization.

8.1.3 If pile edges are adjacent to a river, creek, gulch or other watercourse that might reasonably be expected to erode the edges during periods of high water, the exposed slopes shall be stabilized and the edges shall be diked and riprapped sufficiently to prevent erosion of the pile.

8.1.4 Drainage ditches shall be provided around the pile edges sufficent to prevent surface runoff water from neighboring land from reaching and eroding the pile.

8.1.5 The pile shall be stabilized against wind and water erosion. The method of stabilization may consist of vegetation or a cover of soil, soil containing rock or stone, rock or stone, cement or concrete products, petroleum products, or any other soil stabilization material presently recognized or which may be recognized in the future, or any combination of the foregoing as may be required for proper protection from wind, or water erosion.

8.1.6 Access to the stabilized pile area shall be controlled by the operator or owner and properly posted.

8.1.7 The pile shall be maintained in such a manner that excessive erosion of, or environmental hazard from radioactive materials does not occur.

8.1.8 The owner of the tailing pile site shall give the Colorado Department of Health written notice ten (10) days in advance of any contemplated transfer of right, title or interest in the site by deed, lease, or other conveyance. The written notice shall contain the name and address of the proposed purchaser or transferee. Prior written approval of the Department shall be obtained before the surface area of the land shall be put to use and it shall have been determined that the radiation dosage to the public resulting from the proposed use does not exceed 0.5 rem per year.

8.1.9 With the exception of use at a mill or for reprocessing at the site or another location, prior written approval of the Colorado Department of Health must be obtained before any tailings material is removed from any active or inactive mill.

8.1.10 Detailed plans for stabilizing tailings piles shall be submitted to the Colorado Department of Health for review and approval prior to undertaking stabilization of the pile.

8.1.11 The State Board of Health may waive individual requirements in regard to stabilization or utilization of tailings material if it can be shown that they are unnecessary or impracticable in specific cases.

8.1.12 The effective date of this regulation shall be 45 days after the date of adoption.

Adopted: December 12, 1966